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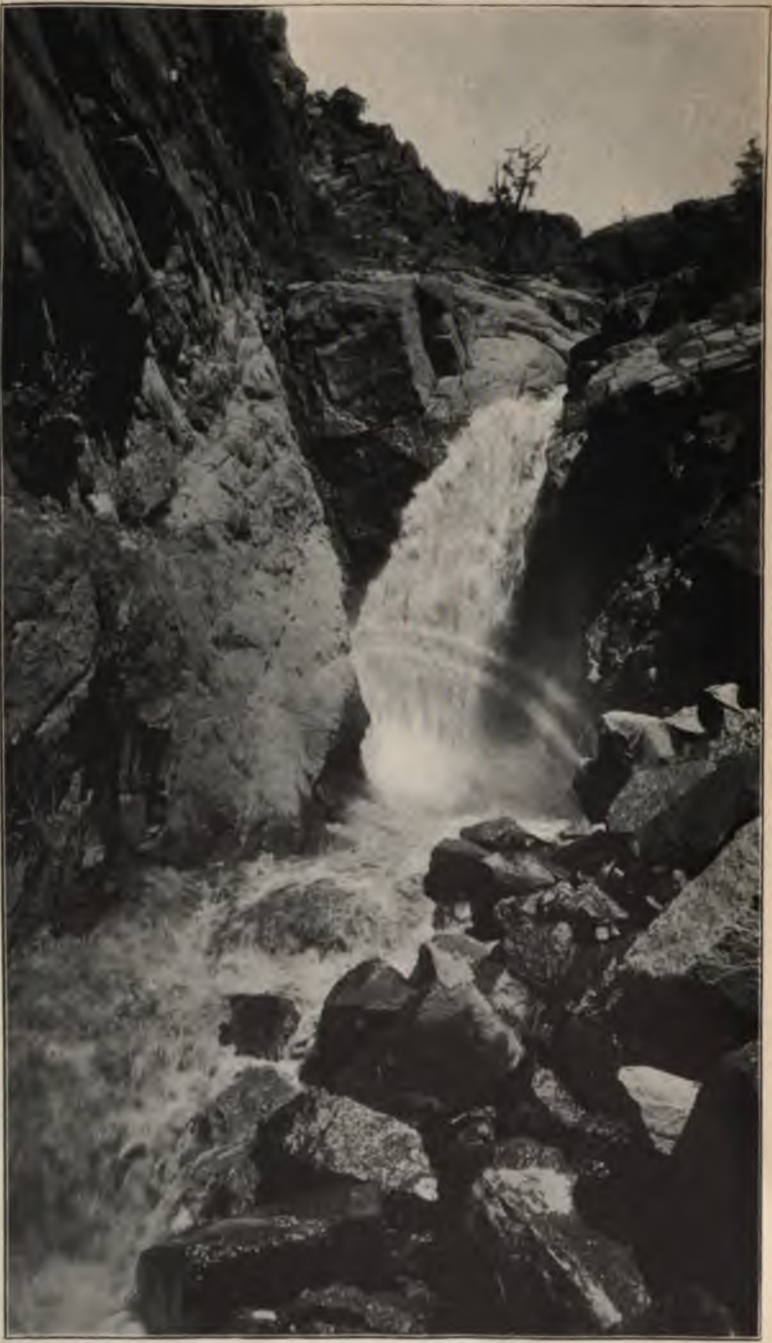

PLATE I.—RAINBOW FALLS, UTE PASS ROAD.

COLORADO SPRINGS

A GUIDE BOOK

DESCRIBING *the* ROCK FORMATIONS
in the VICINITY *of* COLORADO SPRINGS

L. C.

By

George Irving Finlay, Ph. D.
Professor of Geology, Colorado College

With 42 PLATES AND A MAP

THE OUT WEST COMPANY
Colorado Springs, Colo.

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The name "Manitou Canyon" is used in this work for "Williams Canyon," as being the original name, although the latter has been in general use for many years. "Camp Creek" is used for "Glen Eyrie Creek" in the same way. The old names are found on the map.

ERRATUM On page 12, line 24, for "See table on page 60," read "See table on page 58."

On page 61, next to last line, for "Plate 12," read "Plate 16."

Introductory.

THE excursions described in this book cover all the points of interest in the Colorado Springs region which the traveler ordinarily visits. The explanations are written to give the beginner in geology an adequate understanding of the way in which the rocks he meets were formed, and to acquaint him with the processes which have shaped them. The average traveler has a lively interest in these questions, but it is difficult for him to get an answer for them which is available on the ground. The places of special interest are severally treated for what they show best. The Ute Pass excursion deals especially with the granite. Manitou Canyon* exhibits a superb section of the lower members of the sedimentary rock series. In the Garden of the Gods the same sedimentary rock series has been affected by folding movements in the earth's mass. Pike's Peak, Cheyenne Mountain, and Monument Park are striking instances of special phases of erosion. A section of the book is devoted to an account of fossils, and a list is given of the places near at hand where the search for fossils is pretty sure to be rewarded. Other sections take up the account of the formation of coal, and the way in which the Cripple Creek gold ores were deposited. The last chapter builds on all that has gone before to give the reader a general view of the geological history of the Colorado Springs region. The illustrations in the text are intended in the first place as a record in pictures of the country the traveler has visited. They serve, as well, to fix exactly for him the points he is to examine with care, and they make plain many geologic features themselves.

*NOTE— The original name, "Manitou Canyon," will be retained throughout the text for the canyon near Manitou which is generally known as "Williams' Canyon."

Geology should be taught in the field. There are few regions where so wide a range of geologic facts may be observed within small compass as near Colorado Springs. The traveler should read the account of each excursion before going into the field. He will then be prepared when he finds himself in the canyons, or on the mountains to follow intelligently a line of observation toward the acquisition of a chapter in the geologic story. The facts brought out in the descriptions are of general application, but only such features are described as may be seen in the Colorado Springs field.

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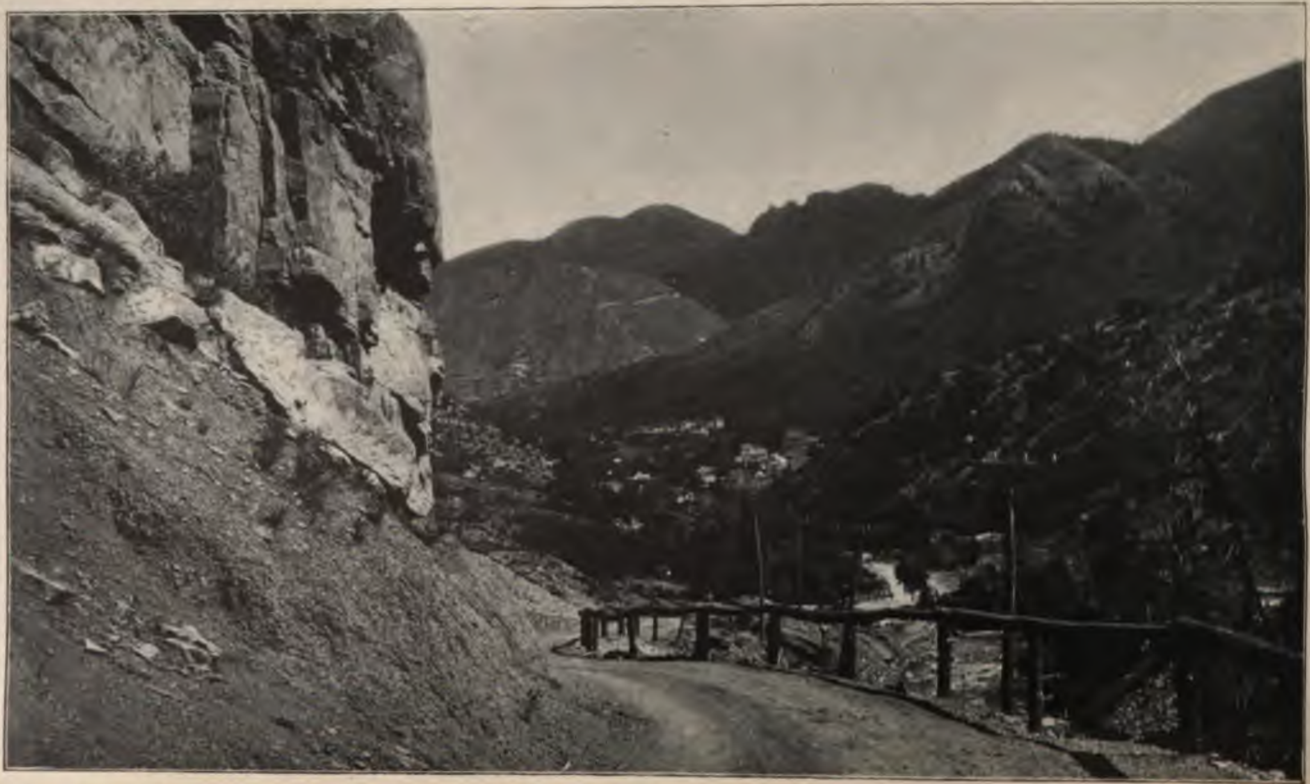

PLATE 2.—CONTACT BETWEEN THE GRANITE, (BELOW), AND THE CAMBRIAN SANDSTONE, (ABOVE), UTE PASS ROAD NEAR RAINBOW FALLS.

Excursion 1.

The Ute Pass.

ON leaving the end of the car line in Manitou, a walk along Manitou avenue and the Ute Pass road for a mile brings one fairly within the granite region, which marks the first chapter in the making of the land as we now have it in the Pike's Peak district. A stop may conveniently be made at Rainbow Falls. Plate 1. Here the river flows over granite; and one may see walls of this rock rising on either hand above the falls.

The method of formation for the granite was by fusion. The rock was once molten. It grew cold deeply buried in the earth before it came to the surface where we now see it. Granite is a typical representative of one great class of rocks, those which cooled from a molten state. In the case of granite the cooling went on with extreme slowness, under great pressure. Other rocks in the same class are the lavas from volcanoes, poured out from volcanic vents at the surface of the earth. These have cooled rapidly under no great pressure. Lavas are found in the Colorado Springs region at Cripple Creek. That town lies on the site of an extinct volcano.

The granite along Ute Pass is made up almost entirely of three common minerals, quartz, orthoclase feldspar, and mica. The mica is the easiest to recognize. It is known familiarly in commerce as ising-glass, when it occurs in large transparent flakes. In the granite the pieces of this mineral are a quarter of an inch across, or less. Mica splits up with singular ease. Its property of splitting in one direction is more highly developed than that of almost any other mineral. Its black leaves are readily distinguished from the other constituents of the granite by putting a knife-point between them and testing the ease with which they break away. A second prime constituent of the rock is white quartz. This is the mineral which is at the basis of the glass-making industry when it occurs in quantity, alone. Certain sands are 99¾ per cent. pure quartz. The best means of identifying it is by its glassy appearance. It breaks as glass would, not regularly, but with a splintery uneven fracture. Its substance is often clear and transparent, although it may at times be colored strongly with dust-like impurities. It looks darker in the granite than it would if it were alone, for the reason that one sees through it the opaque minerals behind it. Besides the mica and the quartz, the other important mineral in granite is orthoclase feldspar. This is responsible for the color of the rock as a whole. It is prevailingly reddish, and uncommonly dark in the rock where one first comes in sight of Rainbow Falls. This is the point shown in Plate 2. Orthoclase feldspar is a valuable mineral when it occurs by itself. It is ground and fused as the chief constituent of porcelain ware. Orthoclase feldspar is opaque; it breaks evenly in two directions at right angles to each other. These cleavage faces will flash in the sunlight, as a mirror would, when the rock which contains them is held at the right angle to the rays. Orthoclase is most often pinkish or flesh colored, and the deeper shades are found in the pieces of the mineral which contain the most brick-red iron dust. One or two per cent. of iron, present in the mineral as an impurity, will stain it deeply.

The experiment has often been tried of grinding such an igneous rock as granite to powder and fusing it in a furnace capable of maintaining high temperatures. If the resulting melted rock be cooled very gradually, allowing the process to go on for five or six days with a lessening temperature and without chilling, until at last the solid condition is reached, it is found that the same minerals have

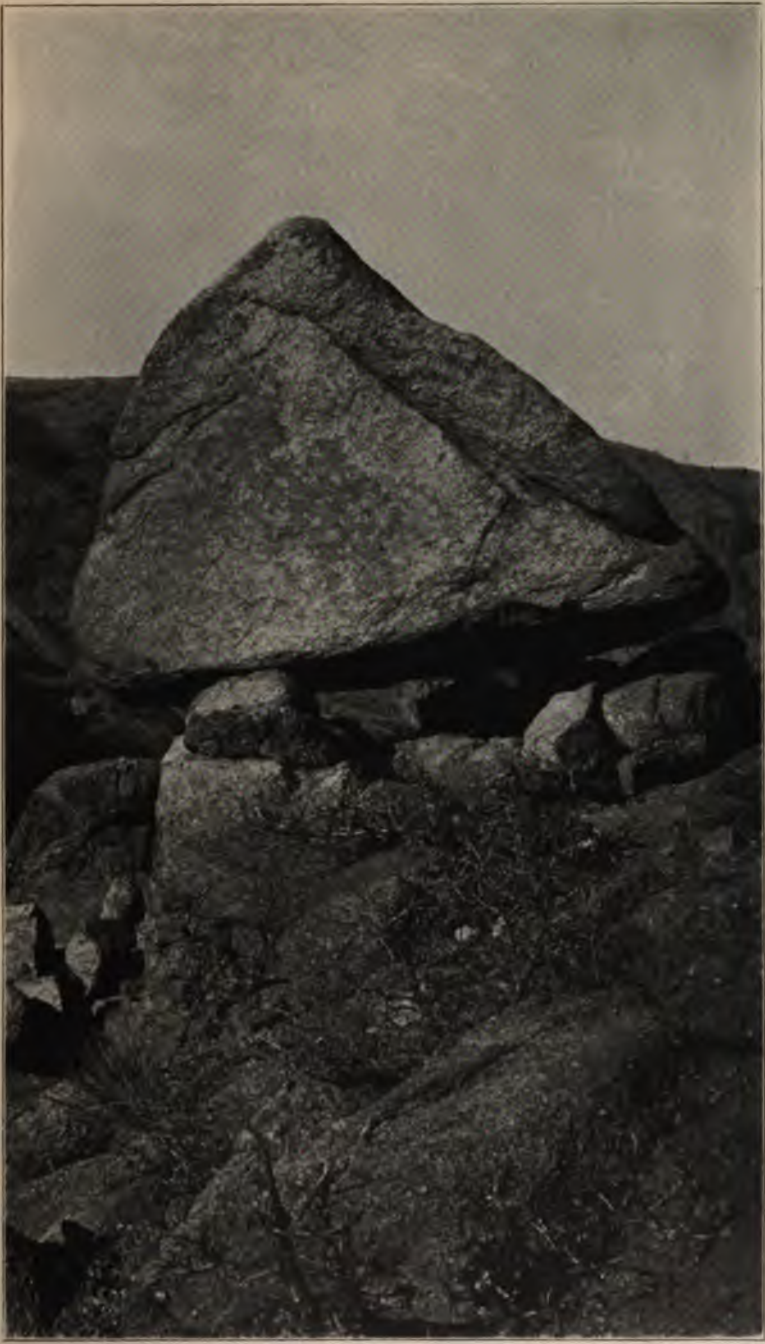

PLATE 3.—GRANITE BLOCK LEFT BY EROSION OF THE SUPPORTING MASSES BENEATH IT, UTE PASS ROAD.

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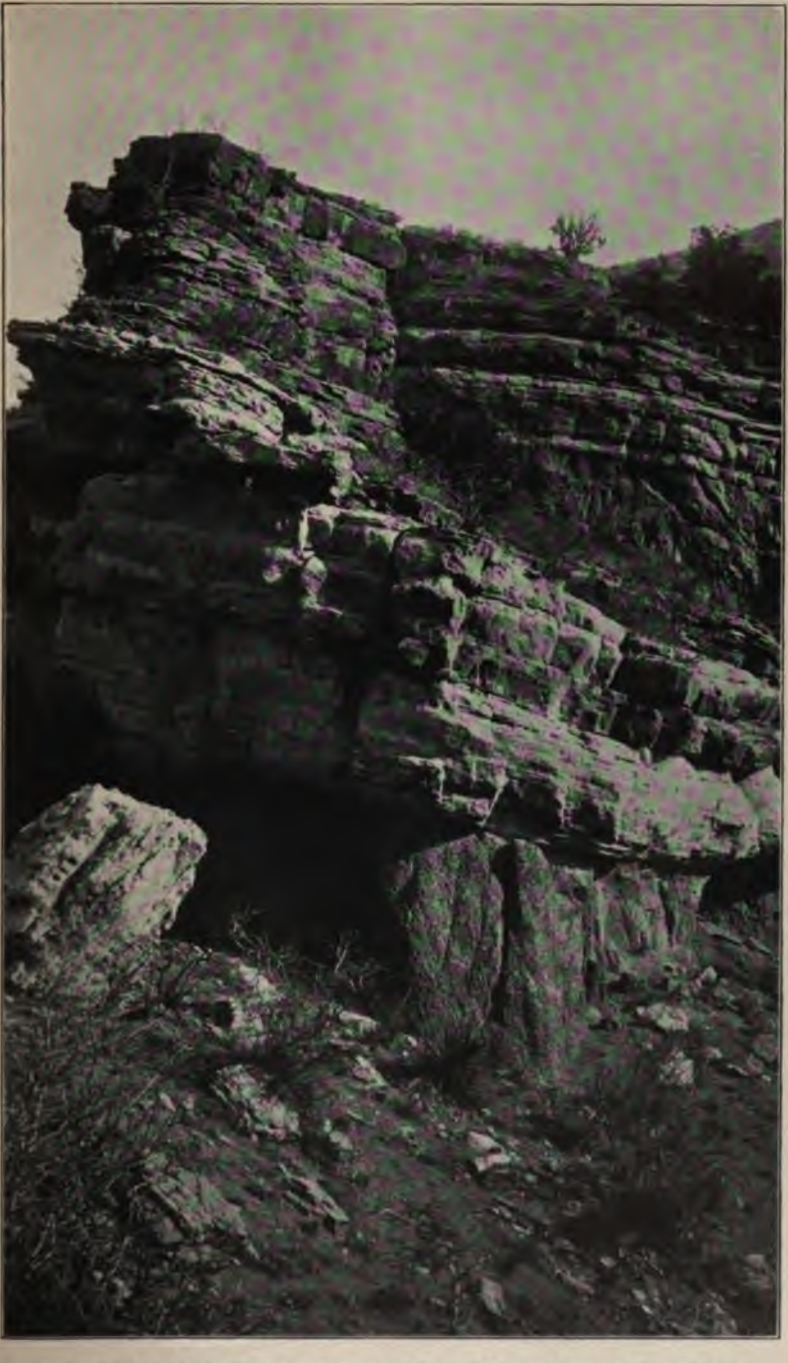

PLATE 4.—CAMBRIAN SANDSTONE OVER GRANITE, ABOVE UTE PASS ROAD TO THE NORTH.

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begun to take form as crystals which went to make up the original rock specimen. Such large crystals as occur in granite have never been obtained experimentally, but it is fair to suppose that were it possible in the laboratory to subject the cooling rock to great pressure, and to make the cooling process last for a period of years, granite would result. The stony masses which we do get in the crucible are in all essentials like natural lavas poured out from volcanoes. By lengthening the time of cooling larger and larger crystals may be produced. It is believed therefore, with reason, that granite rock has formed in the earth in all cases at a distance of several miles below the surface, where great pressures prevail, and where the cooling must be slow. Granite is found where we now see it only because it has been continuously upraised for long periods of time while all the rock that once lay above it was unintermittently removed bit by bit.

A very slight examination of the granite along the road is sufficient to show that it, too, is a prey to the untiring agents of dissolution. The rock is seamed by countless cracks large and small. Under the microscope it is seen to be shot through and through by minute crevices. Water moves with ease through all these cracks and dissolves the rock particles along their walls, with extreme slowness, but unceasingly. Rocks decay continually by the action of surface waters which soak down through the soil and make their way through their pores. When plants decay in the soil certain acids result as products of decomposition. These acids are taken up by the surface rains and aid greatly in increasing the solvent power of pure water. When water freezes it must expand. Throughout porous rock water is often frozen, and a certain amount of riving takes place. Large and small pieces along the cliff-faces break off and fall away until in process of time great heaps of slide rock are made, mantling the lower slopes. They become so steep that any newly added rock particles are apt to roll all the way to the bottom on them. See Plate 9.

The fate of every rock exposed to the weather is that in the end it shall be reduced to the condition of rock dust. This is a very slow process, but it never ceases. We get a measure of it in the decay of tombstones. Certain weak rocks go appreciably on the corners and edges in a hundred years, while others of different physical constitution are stronger and may show scarcely any change in the same period of weathering. But in time all will be reduced.

Above Rainbow Falls the granite shows its tendency to split up into hundreds of vertical cracks, and after this initial breaking up, to weather away in rounded forms in place. As one continues up the Ute Pass road beyond the falls, one may see where many great rounded masses of granite have broken away in times past and have fallen down beside the stream. Many more are in process of transit down the valley sides. On going up the road which leads from the Ute Pass toward the Grand Caverns, one sees at the first sharp turn a granite block in a precarious position owing to the removal in large part of the supporting masses beneath it. Plate 3. Leaving the road at this point one should cross the stream and go out on the ridge opposite the rock mass shown in Plate 4. This repeats the structure of the cap rock shown in Plate 5, and known as El Capitan. From this point one gets the view, half of which is shown in Plate 6. On either side of the river one sees that the rocks which rest upon the granite are unlike it, as being in layers. The lowest of these is the white sandstone at the base of El Capitan, lying immediately upon the granite. See Plate 5. This layer of white sandstone was once continuous across the Ute Pass. The edge of it is seen in a continuous band running up from the river below the falls on the left (north), until it appears under the house at the entrance to the cave. On the other side, to the south, its line is seen over the granite without a break for a quarter of a mile. Plate 6. El Capitan is only a small remnant of the once continuous

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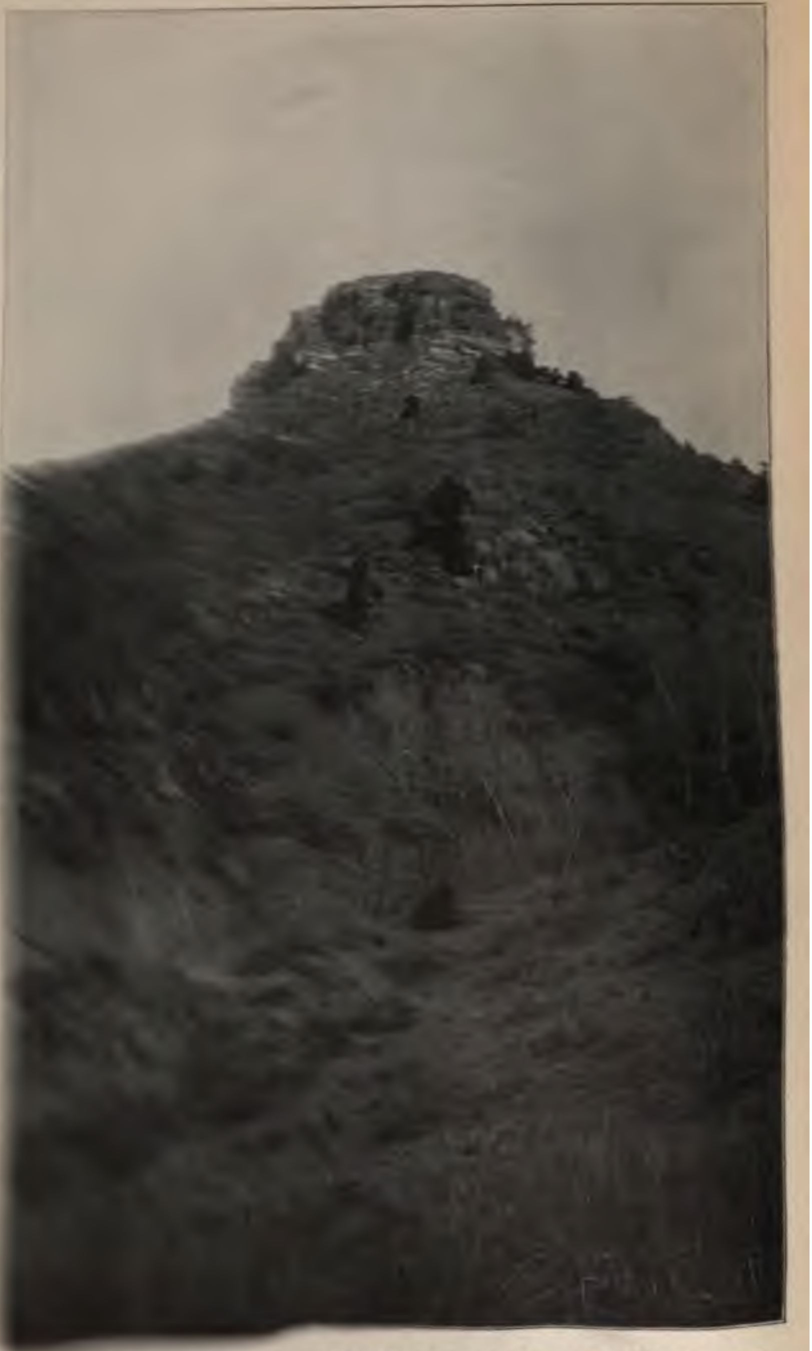

PLATE [illegible]. EL CAPITAN. REMNANT OF SANDSTONE LAYER, [illegible] GRANITE, WHICH ONCE EXTENDED ACROSS THE UTE PASS.

sheet of sandstone. Another remnant like it to the east, is that shown in Plate 4. The sandstone layer resting immediately upon the granite in El Capitan exactly matches the sandstone layer on either side of the Ute Pass where it shows above the granite. It appears, then, that this sandstone band in former time extended clear across the valley from side to side and that it has been so cut away that only the fragments of it like that on El Capitan remain in the middle ground. The stream which follows Ute Pass in making its valley has cut away a good deal of the sandstone and of the granite underlying it. In the same manner the little stream on the other side of El Capitan toward the cave has cut out a valley for itself, working through the sandstone and into the granite. The processes of river work may be studied to advantage in North Cheyenne Canyon, Excursion No. 4. The nature of the banded or sedimentary rocks, of which the white layer of sandstone was the earliest to form, is taken up in the second excursion, in Manitou Canyon.

The observer looking toward Manitou from the road below El Capitan, is standing near the shore line of the original granite island in the sea which ages ago covered Colorado. As the forces of the weather, rain and frost, and the rivers, working on the old land surface wore down the granite and cut into it, the resulting sands were borne out to sea along the river courses. They settled on the ocean floor and were at last made into the compact sandstone which we find in El Capitan and around the Ute Pass. With the uplifting of the western part of the United States the sea was gradually withdrawn, and the sandstone and later bedded rocks were added to the old land along shore. At the present time the weather and the streams are carrying on the same process in wearing down the land and distributing the broken-up rock as sand, gravel and mud, over the sea floor, to be made into land in distant days to come when the continent rises still higher out of the ocean.

Excursion 2.

Manitou Canyon.

AS one leaves the Soda Spring in Manitou and proceeds up Manitou Canyon beyond the point called the Narrows, Plate 7, where the walls come most closely together, one must notice that the rocks on either hand are all in very definite layers, as was the Ute Pass sandstone lying above the granite. This feature marks the sedimentary rocks: those which are made up of sheets of sand, gravel, mud, or shell fragments, deposited under water. See Plates 4, 40 and 41. It is clear that the lowest layers are the oldest as having been laid in place before the more recent ones were deposited above them. Rarely it happens that the whole series of rock layers after deposition under water is not only raised up out of the sea to make land, as is the case here, but also, later, turned up on end and thrown over. The series is then upside down. In Manitou Canyon, however, the usual condition is met. The layers slope away at a slight angle from the horizontal. Coming down the Canyon toward its mouth, the single beds or strata get lower and lower until they strike the road. They were originally laid down almost horizontally.

Rocks of this kind have been studied by comparison with the layers of similar materials which are now being deposited along shore in the shallow waters of the sea. The process may easily be represented experimentally. If sand and gravel of different degrees of fineness be mixed with thoroughly broken-up clay and thrown into a good sized glass vessel nearly full of water, the larger, coarser

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NOTE.—This canyon is generally known by the name of "Williams' Canyon." The original name is "Manitou Canyon."

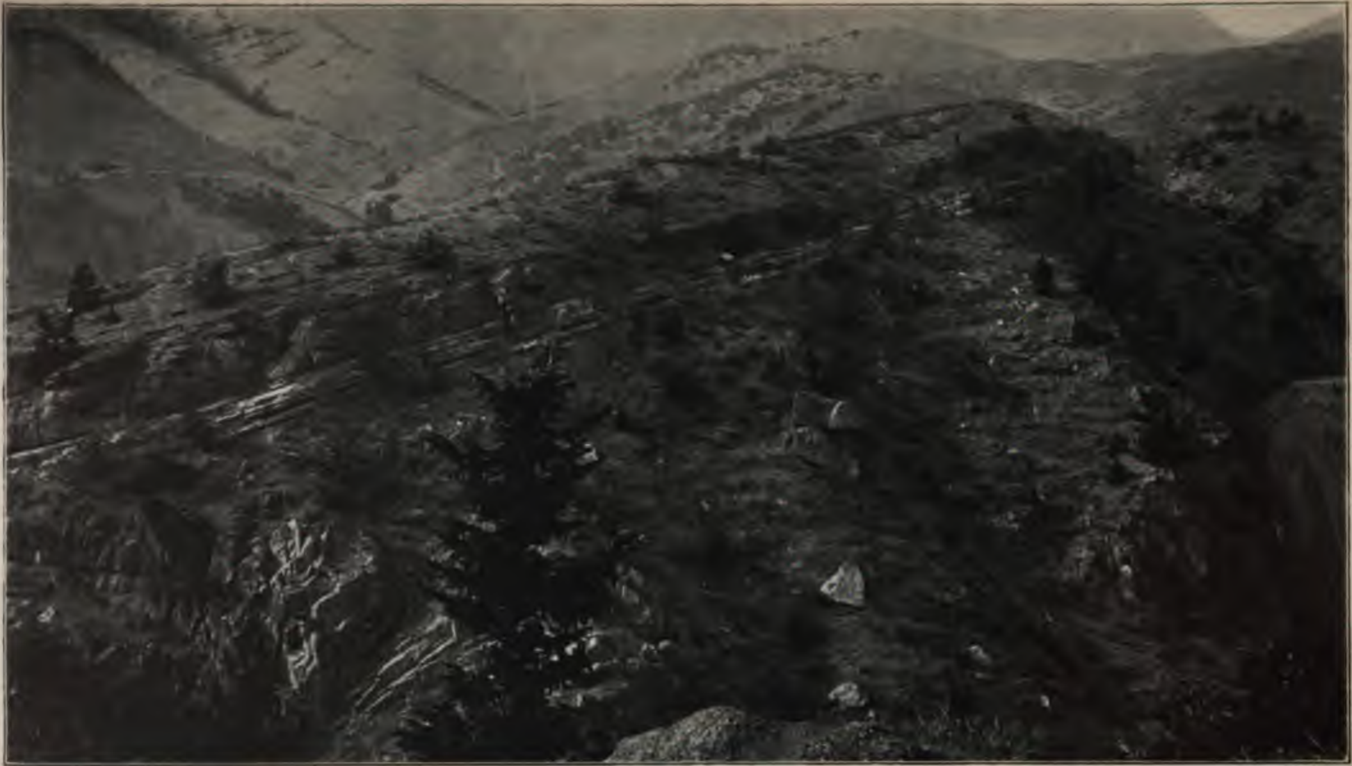

PLATE 6.—CAMBRIAN SANDSTONE RESTING ON GRANITE, ABOVE RAINBOW FALLS, UTE PASS ROAD.

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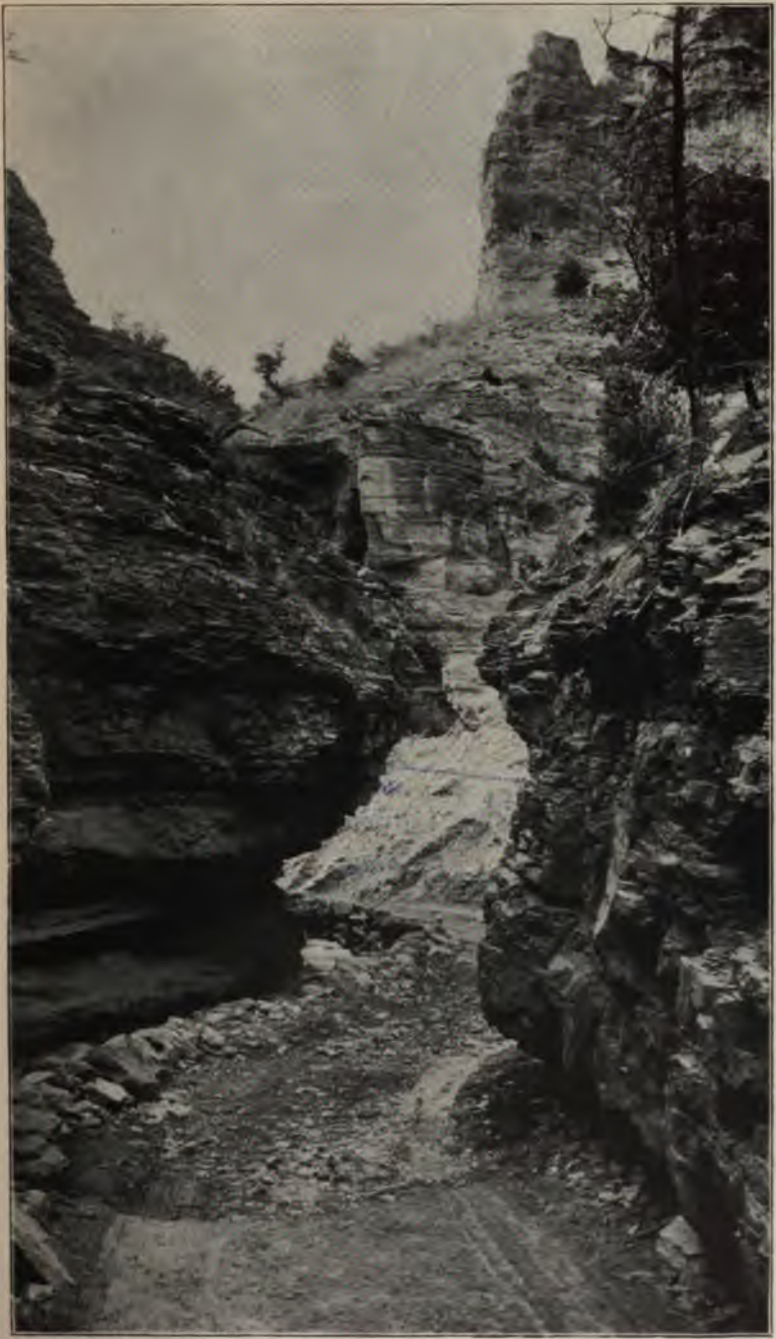

PLATE 7.—THE NARROWS, MANITOU CANYON.

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particles will be seen to fall most rapidly to the bottom. In time all the materials will have settled, leaving the water above them clear. They will lie in horizontal layers of different degrees of fineness, the coarsest layers at the bottom, the finest layers on top. It takes a good while, even in still water, for all the layers to settle. In the ocean the depths are so great that particles may not reach the bottom for many days. Then, too, the water is kept continually in motion by off-shore currents. These accentuate the sorting process, for they are not strong enough to hold up the coarser pieces, although they can sweep the finer particles about for a long time. Their force is variable. At times they may hold up even the coarsest gravels; again they may be so feeble that they will allow their whole load to settle. All these materials are borne out to sea by river waters. The beating of waves along-shore breaks down the rocks along the coast as well. It is easy to realize that the supply at any point over the ocean floor will be of different materials from time to time. At one time fine layers accumulate on the bottom; at others, coarse materials, now of one color, now of another are deposited.

In the Colorado Springs region we have to deal with 10,000 feet of such materials in layers. The question at once arises, "How did they change from their incoherent state and become hard rock as we now see them?" This is accomplished in two ways. The pressure of the layers above, when many hundreds of feet have been deposited in one place, is enormous. The grains in the lowest layers tend to cohere by mere pressure welding, for the pressure is exerted during many hundreds of thousands of years. Again a certain small amount of water was imprisoned between the grains as the layers were deposited on the sea-floor. Water dissolves rocks with extreme slowness, but it may be shown by experiment that water will dissolve every rock. A small part of all the grains is taken into solution by the water between them. When at last the whole layer dries out, the dissolved substance is left as a mortar or cementing bond between the grains. A similar process may be studied advantageously on the Florida coast. Here the waves dash against coral reefs, break away pieces of coral, and toss them about on the beaches until they are ground to fine sand. The waves wear on the hard parts of shell-fish in the same way. Thick banks of sand made up altogether of broken shells are thrown up on the beaches. As the rain-water soaks down through these masses of broken shells part of their substance is dissolved away in the upper layers and left as a natural cement between the grains near the bottom. The loose shells soon become fairly firm rock. The same materials make the same kind of rock in the same way on the sea-floor. This is the origin of limestone. In this case the cement is limy. In the walls of Manitou Canyon we have such limestones. Quartz sands are usually made into hard sandstone through the binding of the grains together by interstitial quartz. Iron is also used in nature as a bond between sand grains. When mud becomes consolidated as a rock, shale results. When gravel and coarser good-sized pebbles are cemented together we call the rock conglomerate. The ultimate drying out process is accompanied by a certain amount of shrinking. Cracks develop between the successive layers, and well-marked beds like courses of brick-work result. See plates 8 and 9.

Limestone, sandstone, and shale, with conglomerate, are the chief sedimentary rocks. They make up about four-fifths of all the land masses. The igneous rocks constitute a large part of the remaining fifth. The other great class is that of the metamorphic rocks. These result when either igneous rocks or sedimentary rocks have been so changed by heat and strain within the earth as to have their substance worked over into new minerals. Mica is the commonest mineral developed in the metamorphic rocks. The plates of mica, as well as the other mineral components of metamorphic rocks, are arranged in wavy lines perpendicular to the direction in which the

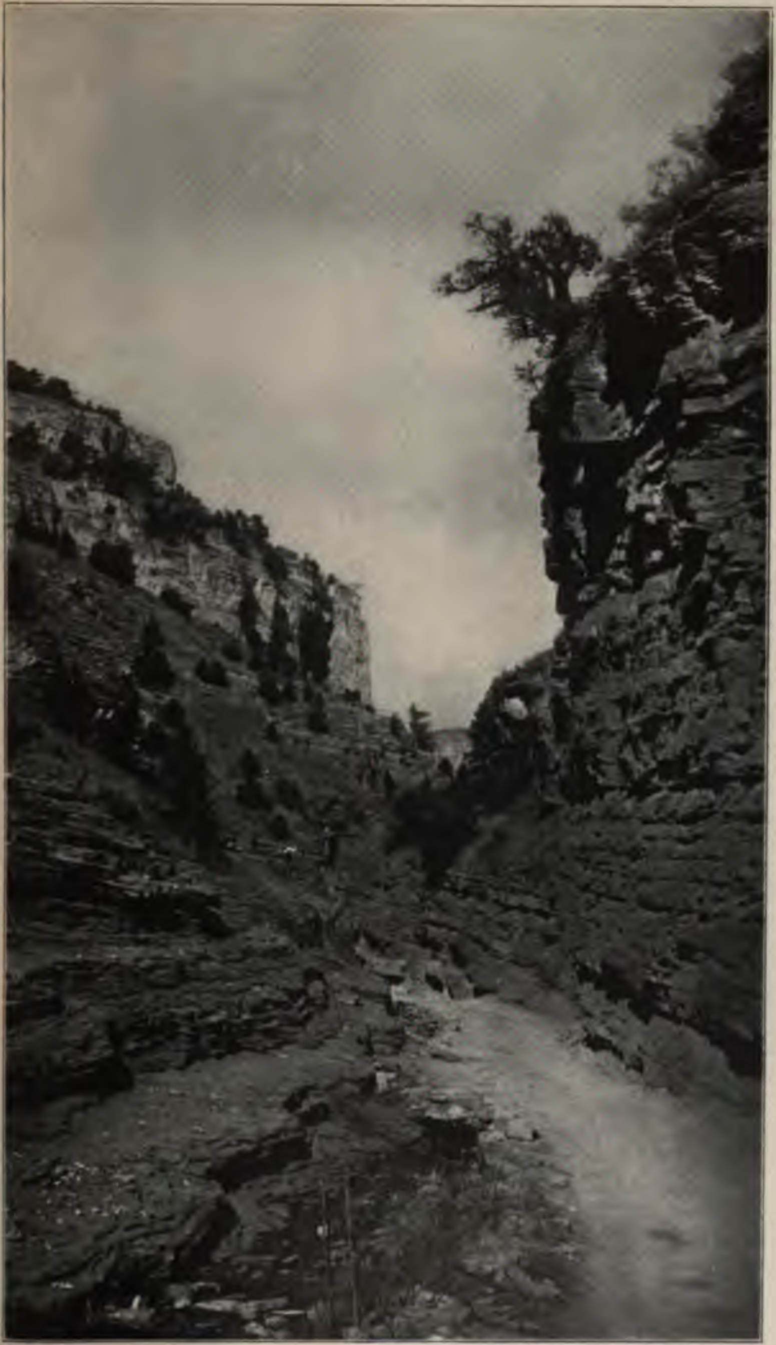

PLATE 8.—MANITOU CANYON UP STREAM FROM THE NARROWS.
CAMBRIAN SANDSTONE ALONG THE ROAD.

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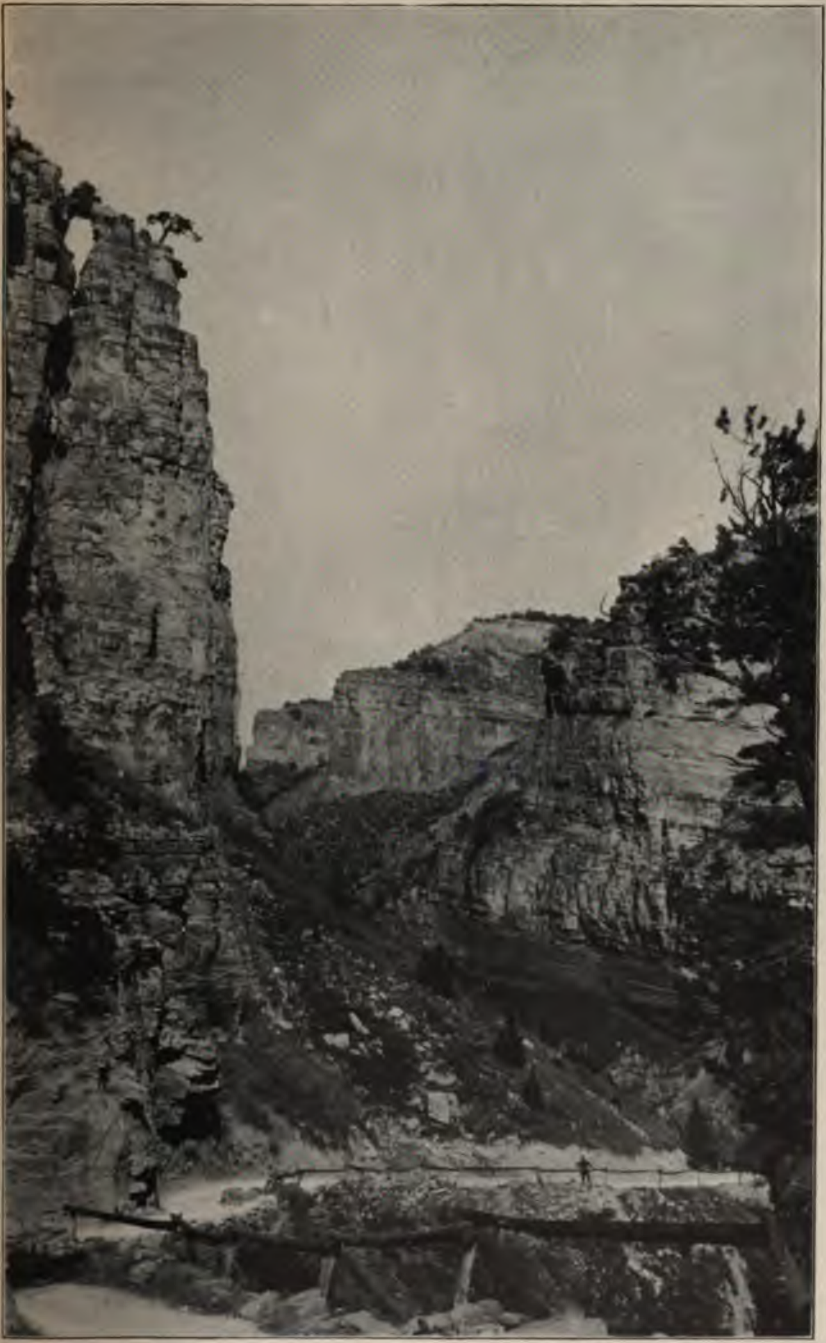

PLATE 9.—MANITOU CANYON. LIMESTONE ABOVE THE ROAD.

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force was applied so as best to accommodate themselves to it. Only one good example of such rocks occurs near Colorado Springs. In Manitou Canyon, just where the road turns and begins to climb toward the Cave of the Winds, the granite has been so metamorphosed that its minerals stand in definite alignment. This rock is called gneiss. It is practically granite with a very definite grain to it.

In Manitou Canyon four rocks occur. The stream flows over granite before it comes down to the road. Just below the point where the road turns to ascend to the cave, the basal rock is gneiss. Layers of sandstone 45 feet in thickness rest upon the gneiss or upon the granite, (see Plate 8), and these are overlain in turn by 250 feet of limestones. The limestone is by far the most conspicuous rock in the canyon. It appears in the upper half to the left in Plate 9, and it makes up nearly the whole of Plate 10. Here the top of the limestone is 300 feet above the road. At the entrance to the canyon, half a mile below, it has come down to the roadway. This illustrates how the sedimentary rocks, originally level, have, as explained above, been tilted away from the horizontal. The point where the sandstone ends and the limestone begins may easily be found. In Plate 9 it is about 1¼ inches above the man in the roadway. Just at the entrance to Manitou Canyon the top plane of the limestone has dropped to the road. Between this point and the Cliff House in Manitou layers of red conglomerate are found. The conglomerate is above the limestone and rests upon it. The attitude of all the layers is like that of a number of books which have fallen toward the empty end of a book-shelf so as to overlap each other. A geologist would make a unit of all the sandstone layers lying just above the granite in Manitou Canyon, another of all the limestone layers coming in on top of the sandstone, and a third volume of all the sheets of red sandstone and conglomerate resting on the limestones. The single layers of rock, marked out by minute differences in texture, and made more pronounced by the cracks parallel with the bedding, are like the leaves of the volume. The geologist finds that nearly every such formation contains the remains of life. Shells of sea-fish which lived on the ocean floor and were covered up at their death beneath subsequent layers are the commonest of these. Any traces of living things are fossils. Each volume, to retain the figure, each rock formation, is marked by distinct fossils. As one goes higher in the series and so comes to more recent rocks, it is found by a multitude of observations that each set of fossils in a given rock is replaced by another set in the succeeding layers above it, with a tendency all along toward more complex and more highly organized forms. By a close study of fossils, going up from stratum to stratum, geologists have acquired a body of precise information as to the fossil contents of each division of the series. It is as though there were 26 great composite layers of rock with fossil contents characteristic of each through the 26 letters of the alphabet. If then in a rock a fossil corresponding to the letter D were found, we should know the place of the rock in the series.

In the Colorado Springs region there are 17 such sets of rock strata from the basal sandstone as it shows in Manitou Canyon to the topmost stratum out on the plains. See table on page 60. During the whole of geologic time the world over, at least 100,000 feet of such broken-up rock materials were deposited and made into sedimentary rock in layers. In the Colorado Springs region a thickness of about 10,000 feet of sedimentary rocks shows as one crosses the country over their upturned edges. The oldest are just against the granite, resting upon it; younger and younger layers are met as one goes out toward the plains. Geologists are not able to assign definite periods of millions of years as the time in which certain masses of sedimentary rock were formed. They know their relative ages since it is clear that the oldest are those which lie at the bottom of the series, and they can tell the age of any one in which they find fossils, because they know the

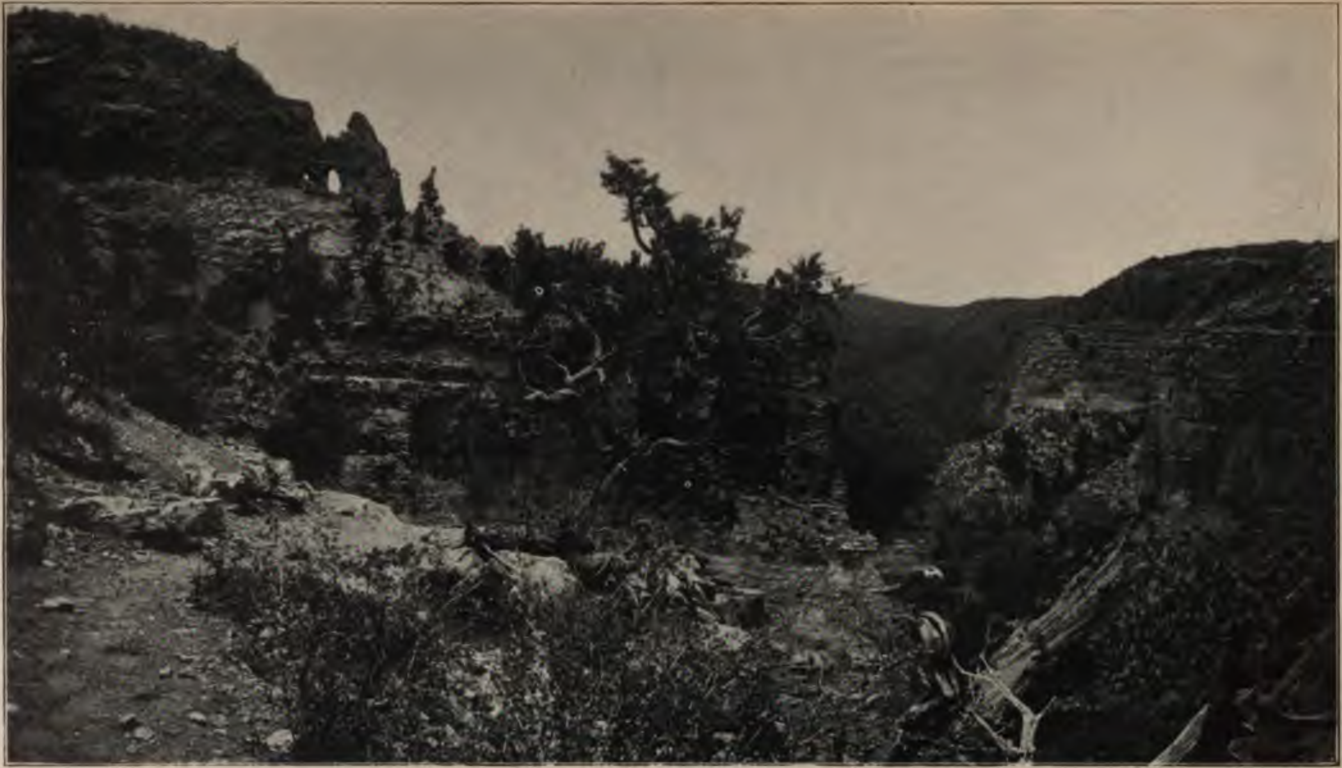

PLATE 10.—UPPER PART OF MANITOU CANYON FROM THE CAVE OF THE WINDS.

place of the fossils in the whole line of living things. Excursion 9, which is devoted to the consideration of fossils at length, gives a list of the localities in Manitou Canyon where they may be found. The succeeding chapter deals with the particular methods by which the materials going to make up the sedimentary rocks were obtained.

Excursion 3.

The Garden of the Gods.

Folding of the Sedimentary Rocks.

IN studying the sedimentary rocks it is well to begin in Manitou Canyon where limestone and sandstone are so well represented. For the study of the sedimentary rock to which we give the name conglomerate, a favorable stretch of country is that between Manitou and the Garden of the Gods. By leaving the car line at the point where the road starts over to the Garden past Balanced Rock, Plate 11, one proceeds over conglomerate and sandstone all the way. The difference between the two is in the relative coarseness of the materials which make them up. Gravel deposited under water in sheets and afterwards hardened, makes conglomerate. The nature of this material is well shown in the rock in Plate 12. The constituent pebbles are many of them two or three inches across. They are in some cases rounded pieces of granite which the old time rivers carried along their courses as the present streams do, until they were swept into the sea. Other pebbles are pure quartz. The brownish red color of the rock is due to the iron present in the cement. This form of iron, ferric iron, is responsible for the color of common burned brick.

By looking attentively at the single sheets of conglomerate with finer layers of sandstone in between, it is at once seen that they are very steeply inclined at the point at the extreme left in Plate 13, along the road near the Garden of the Gods. The sedimentary rocks in Manitou Canyon are not level, Plates 8 and 9, but gently inclined. By noting the sedimentary bands in the rocks in the Gar-

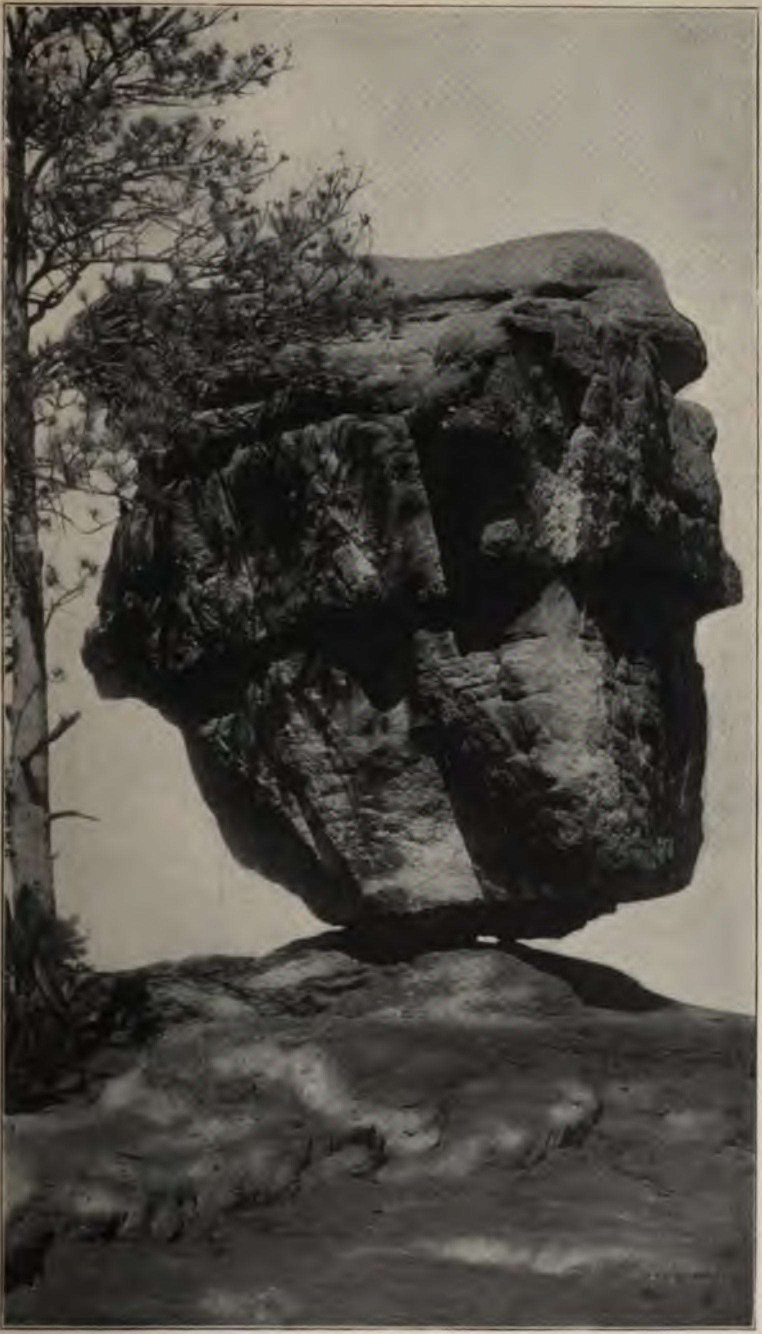

PLATE II.—BALANCED ROCK ALONG ROAD LEADING TO THE GARDEN OF THE GODS FROM THE SOUTH.

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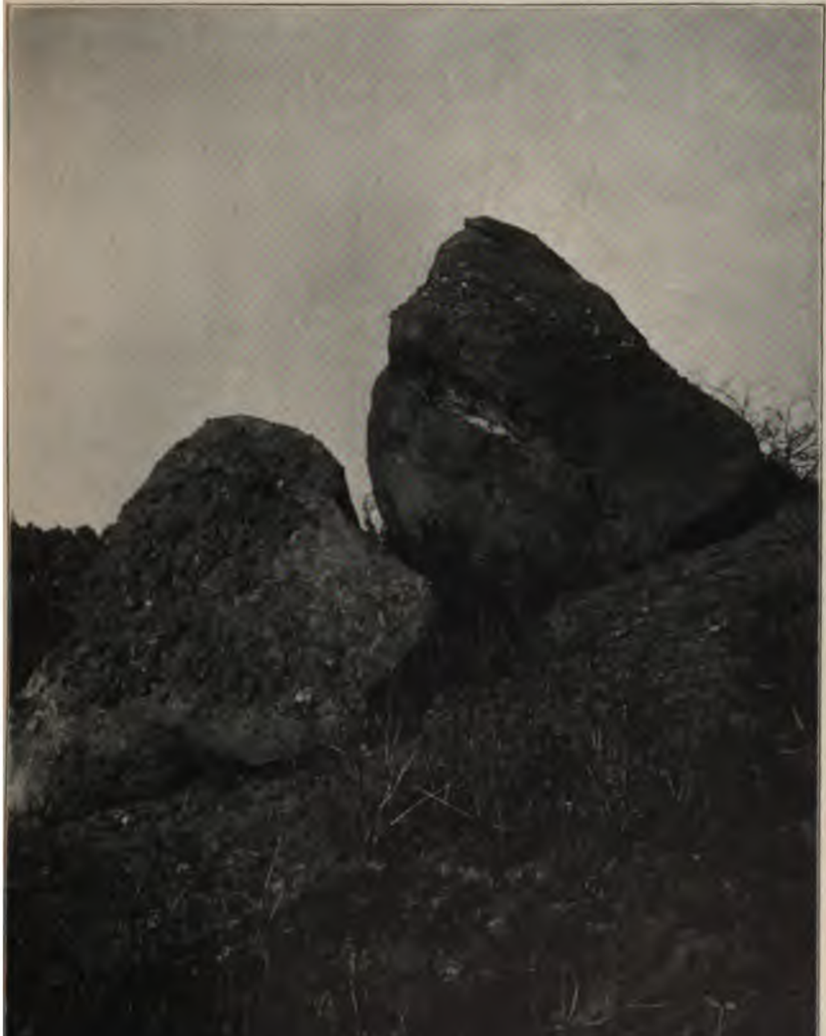

PLATE 12.—CONGLOMERATE BOWLDERS SOUTH OF THE GARDEN OF THE GODS.

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den, it is seen that these strata are vertical. Plate 14, and middle ground, Plate 13. It is as though the sheets originally nearly horizontal under water have been made, as part of the land, to stand up on end. Plate 4 shows the moderate slope of the sedimentary rocks along the Ute Pass. Plate 12, upper block, shows a much greater inclination at a point some distance out from the granite. In the Garden of the Gods the sedimentary layers are vertical. Plates 13 and 14. Beyond Colorado Springs in Palmer Park, they are tilted but slightly.

It is found by many observations the country over that the layers of sedimentary rock may be folded as though one were to take five or six strips of carpet in a pile and by pressure from either end cause them to wrinkle up into many folds. The forces in the earth produce such results in the rocks only very slowly. The resistance offered by the layers is enormous, but tremendous pressures are brought to bear upon them. The length of time involved in the folding operations is a large part of the whole geologic period. At least four or five miles of rock layers down from the surface of the earth are often concerned in the folding movements, and the compressive forces may act slowly and continuously for hundreds of thousands of years. It is evident that during all this time the planing and cutting forces of the weather and the streams have been active at the surface. We commonly find the upper layers cut away. In the Colorado Springs region we always see the cut-off edges of strata cropping out of the ground. See Plate 15.

The foregoing experiment to illustrate folding makes use of lateral pressure. The matter of which the earth is composed comes to be denser throughout the ages, for the self-gravity of the planet makes for condensation. A decrease in the volume of the whole earth would necessitate some folding in the superficial layers, a wrinkling of the crust to accommodate them to a shrinking sphere. The arc must be shortened as the radius is shortened.

Now, if all the folded rocks are imagined as extended flat and the computation be made for the corresponding amount of shrinking on the earth's radius necessary to account for the folding at the surface, the resulting amount is small. To account for the folding the shrinkage incident to greater condensation of the earth in such a time period as 50,000,000 years should be about one two-hundredths of the radius of the earth. Of far greater significance than the rock folding described above, are the massive slow movements in the earth's body which have resulted on the whole in the uplifting of the continental land masses and in the sinking of the oceanic basins. By forces of erosion the land masses would have been worn down nearly to sea level and the broken-up rock materials cut away from them would have done much to fill up the oceanic basins, if these slow massive movements had not been operative again and again.

Near Colorado Springs the folding movements were largely in the nature of vertical thrusts. The Colorado island was made when the granite mass was first pushed into prominence above the ocean waters. All that the elements wore away from it was deposited under water to make the sedimentary rocks which we now have extending outwardly from the granite. Further upraising of the granite mass brought more and more of these layers of sedimentary rock out of the water. In this way Western North America grew. The rocks out over the plains at a distance of six miles or more from the mountains are but slightly tilted away from their original nearly level position. Those as far in toward the mountains as the Garden of the Gods have been made to stand up on end. Still farther in, immediately adjacent to the mountains, the layers are tilted at angles of 20 or 25 degrees away from the horizontal. We can see in the Ute Pass or in Manitou Canyon that the lowest sedimentary rocks rest upon the granite as upon a platform, but it is not known how far out under the sedimentary rocks the granite platform ex-

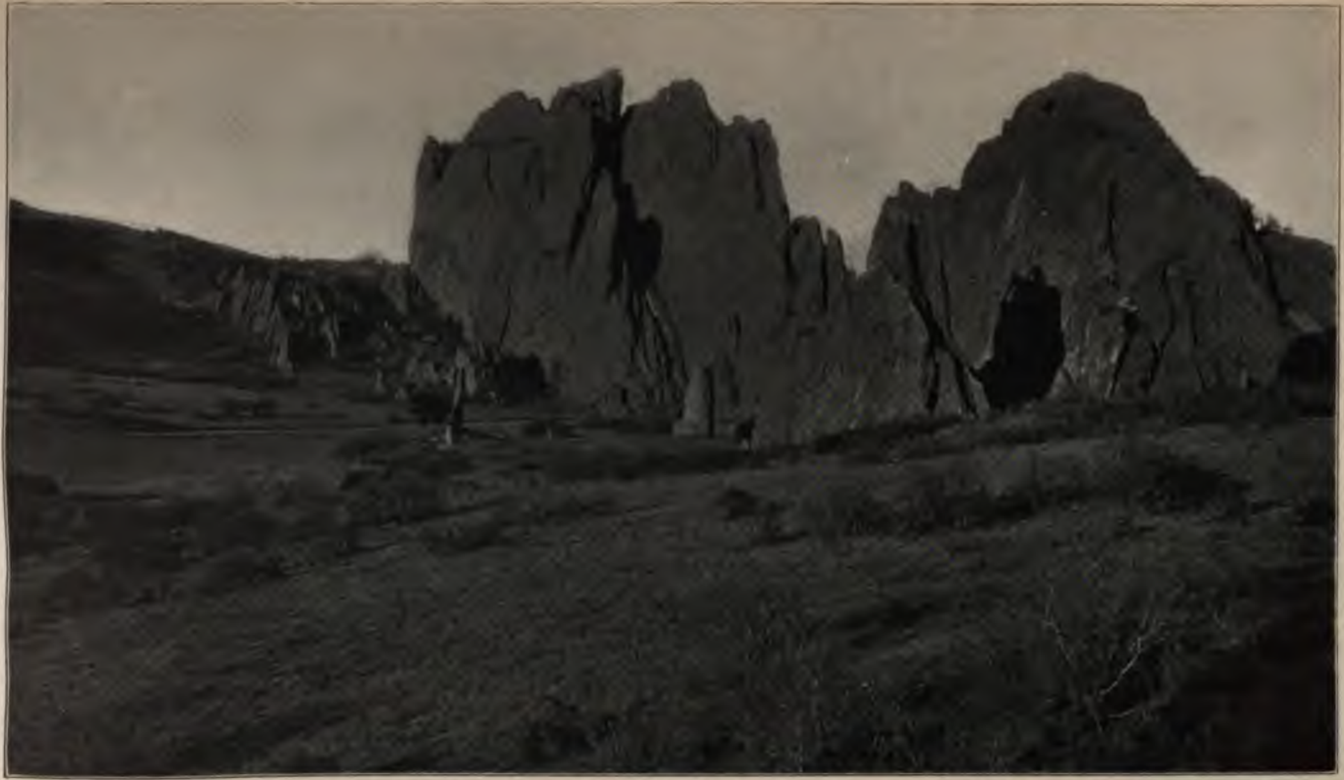

PLATE 13.—GARDEN OF THE GODS FROM THE SOUTH.

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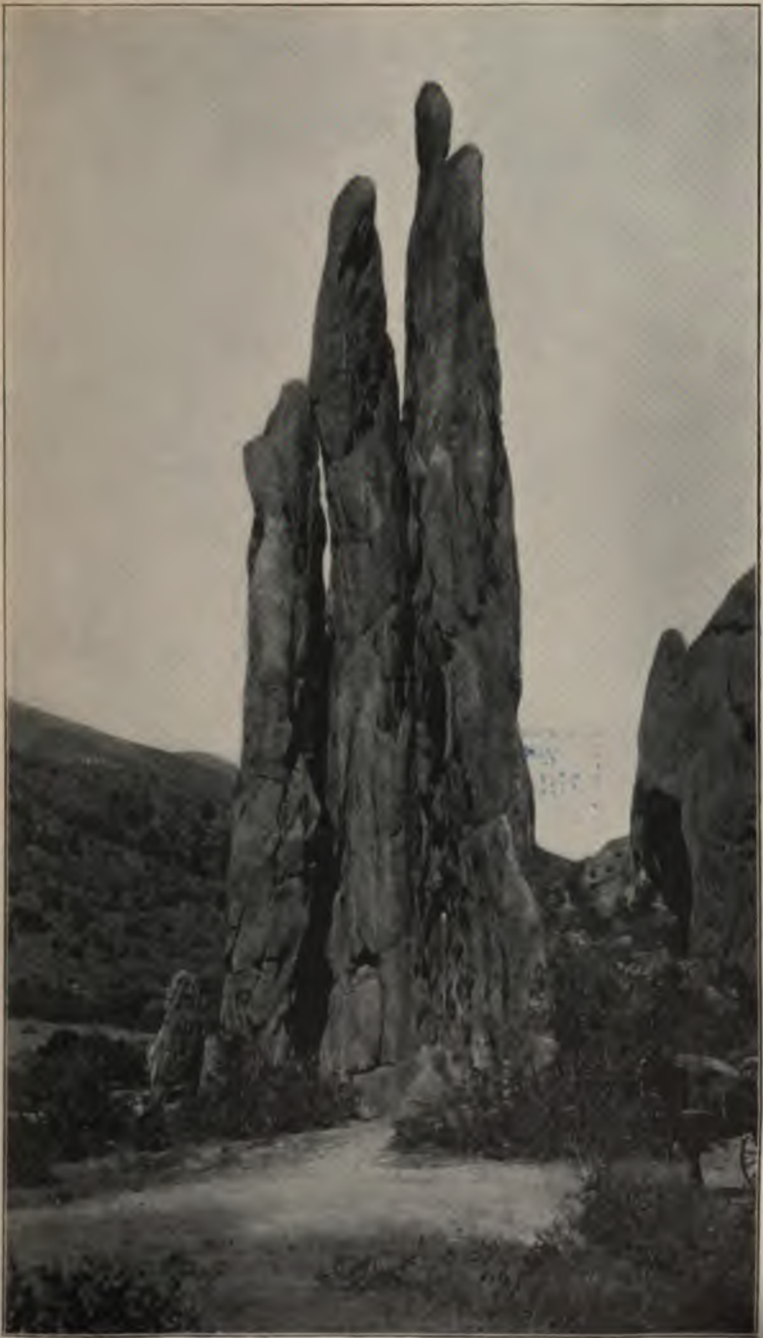

PLATE 14.—SANDSTONE IN VERTICAL LAYERS, GARDEN OF THE GODS.

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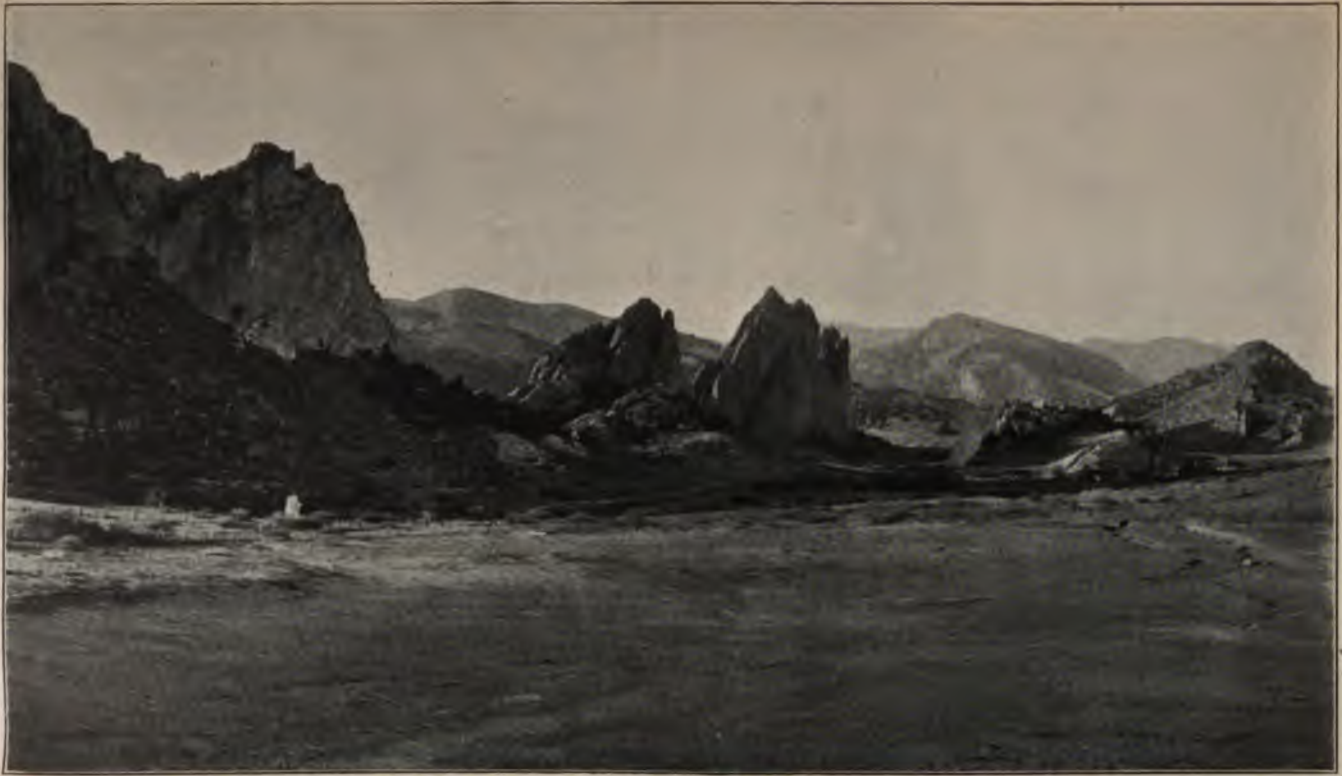

PLATE 15.—VIEW LOOKING NORTHWEST TO THE GARDEN OF THE GODS.

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tends. To account for the differences in the inclinations of the sedimentary rocks above the granite platform which were influenced by its uplift, two explanations may be offered. The condition may be brought home to the reader by his taking a handkerchief, extending it upon a table, and then lifting it partly off the table by means of a book placed under the edge of the handkerchief and slightly inclined toward it. The book represents the granite platform. That part of the handkerchief resting upon it is slightly inclined as the book is. Some of the handkerchief lies on the table undisturbed, and a part of it just over the edge of the book is made to stand vertically. This is the nature of the flexure observed in the layers of rock between the mountains and the plains beyond Colorado Springs to the eastward. We may presume that one of two conditions is the fact. Either that the granite platform extends under the sedimentary rocks only as far as the Garden of the Gods, or that a break came along a great north and south fissure in the granite platform under the rocks at the Garden of the Gods and that the mountainward block went up while the block toward the plains did not. The diagram at the top of Plate 16, Figure 1, illustrates the conditions.

But the peculiar rock masses in the Garden of the Gods do not owe their prominence to the effects of uplift and folding, though it is true that they are composed of strata which have been pushed up to stand vertically. They have been stronger to resist the downcutting forces of the weather than the rocks around them. They are sandstones in which the bond between the grains has been firmer than it appears to be elsewhere along the layer of which they are a part. Actual decay under the weather, the riving action of frost as water freezes in the porous places in rock, and the cutting effected by streams of running water have given to the red sandstones in the Garden their peculiar sculptured forms, but they have not been able to reduce them as effectively as they have the surrounding weaker rocks. Such a result is due partly to the ability of the sandstone masses to resist the attack of erosion better than their fellows, and to some extent to their accidental position so that they are in a measure out of the way of active streamlets.

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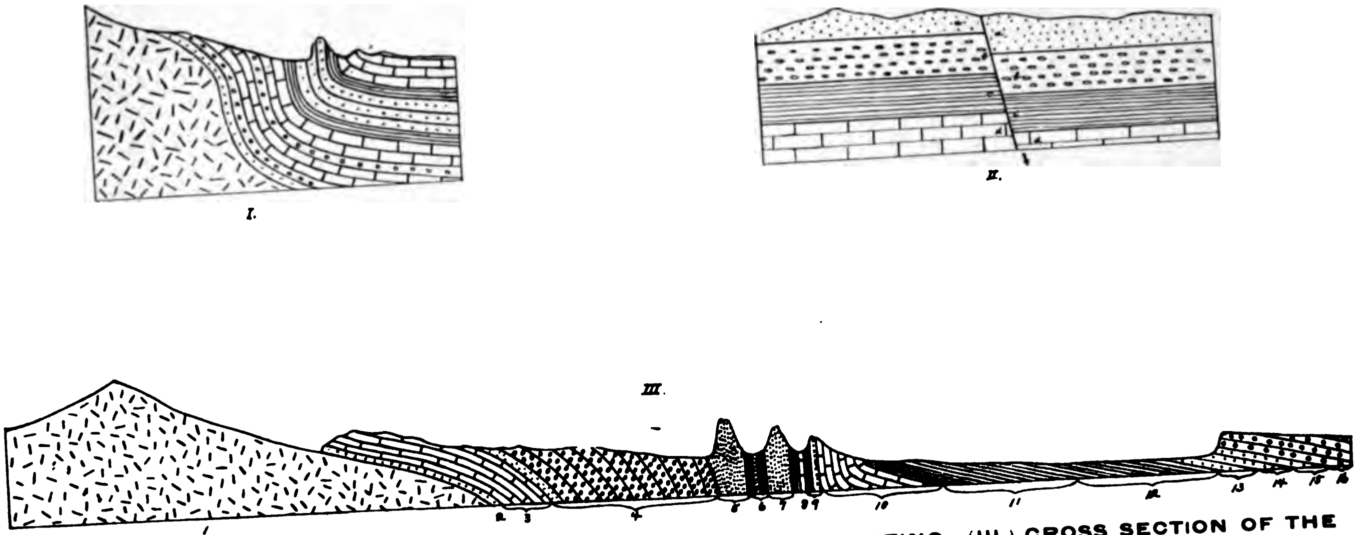

PLATE 16. DIAGRAMS TO ILLUSTRATE (I.) FOLDING AND (II.) FAULTING. (III.) CROSS SECTION OF THE COLORADO SPRINGS ROCK SERIES.

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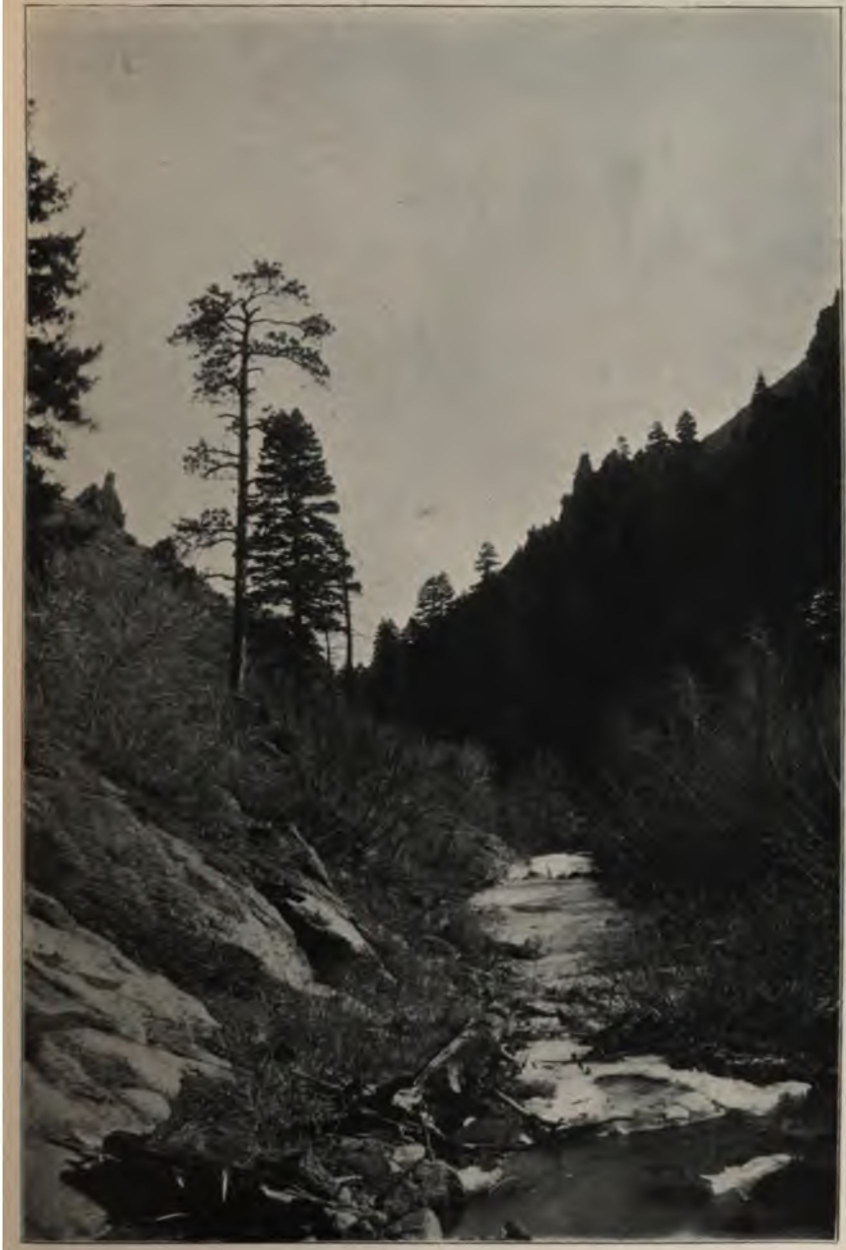

PLATE 17.—NORTH CHEYENNE CANYON DOWN STREAM FROM THE WATERFALLS.

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Excursion 4.

North Cheyenne Canyon.

River Work.

RIVERS are fed by melting snows, by the rainfall, and by springs issuing along their beds. During the rains a considerable amount of the water does not run away directly, but soaks into the soil and pursues a long, slow course underground through the crevices and fissures in the rocks. At a certain variable distance below the surface a great body of water of this kind is met with. Wells which are driven far enough to meet it will not run dry. In the same manner when a river has deepened its bed sufficiently it reaches the body of ground-water. It does not then depend altogether upon local precipitation for its flow, but becomes perennial. This is the condition of such streams as North Cheyenne Creek.

A certain amount of decay takes place when rain-water soaks through the rock masses. In the upper layers of the soil decaying vegetation yields acids which materially increase the solvent power of water. Frost in the cracks of the rocks, as water freezes, acts as a wedge to rive portions of the rocks away. By these activities of the weather the rocks are broken up in the first place, and prepared for the effective cutting action of the streams running upon them. Gravity helps greatly, for loose rock particles are continually made to roll down the valley slopes as their supports give way. The sweep of rain-water in sheets is also effective at the surface in carrying the rock particles down hill.

In every gulch, in every ravine, and in every valley, running water takes the broken-up, partially decayed rocks and accomplishes a great amount of cutting with them. Water by itself could do no cutting. With gravel and sand, however, a stream can grind its bed very effectively. The amount of finely ground-up rock which rivers sweep along in their muddy currents has been repeatedly estimated. It is found to be on the average one part by weight in 1,500. The waters dissolve smaller amounts of the rocks over which they pass. The dissolved material is about one part in 5,000 by weight. The calculation has been made for the Mississippi that by these means the river is lowering the whole land which it drains one foot in 6,000 years. The body of water in a stream is rapidly flowing down to lower levels. But where the bed of a river is irregular and strewn with rocks, local currents are constantly formed and are forced to sweep upward over the obstructions. These currents carry sand and mud upward with them so effectively that, if it be fine grained, it is a long time in a strong stream before it reaches the bottom again. The rubbing action of sand, gravel, and small pieces of rock in a stream quickly takes the corners off the larger blocks. The average stone from the bed of a stream or from a river bar is beautifully rounded. A smooth, egg-shaped outline is the mark of water-worn material. Ultimately all the pieces by rubbing against one another or by sweeping across the bed rock of the stream are reduced to fine sand and mud. The power of running water to push pebbles and cobbles along before it increases very rapidly as the velocity of the current is made greater by floods. A stream flowing at the rate of 2 miles per hour will move rounded stones as large as a hen's egg. If its velocity is increased to five miles an hour it can move cobbles weighing 3 or 4 pounds. North Cheyenne Creek may be seen at all times bearing sand along, and, after heavy rains, pushing forward large and small pieces of rock which have been swept in by rain or have rolled down from the canyon walls. Plate 42. Examination at one of the bridges a short distance up from

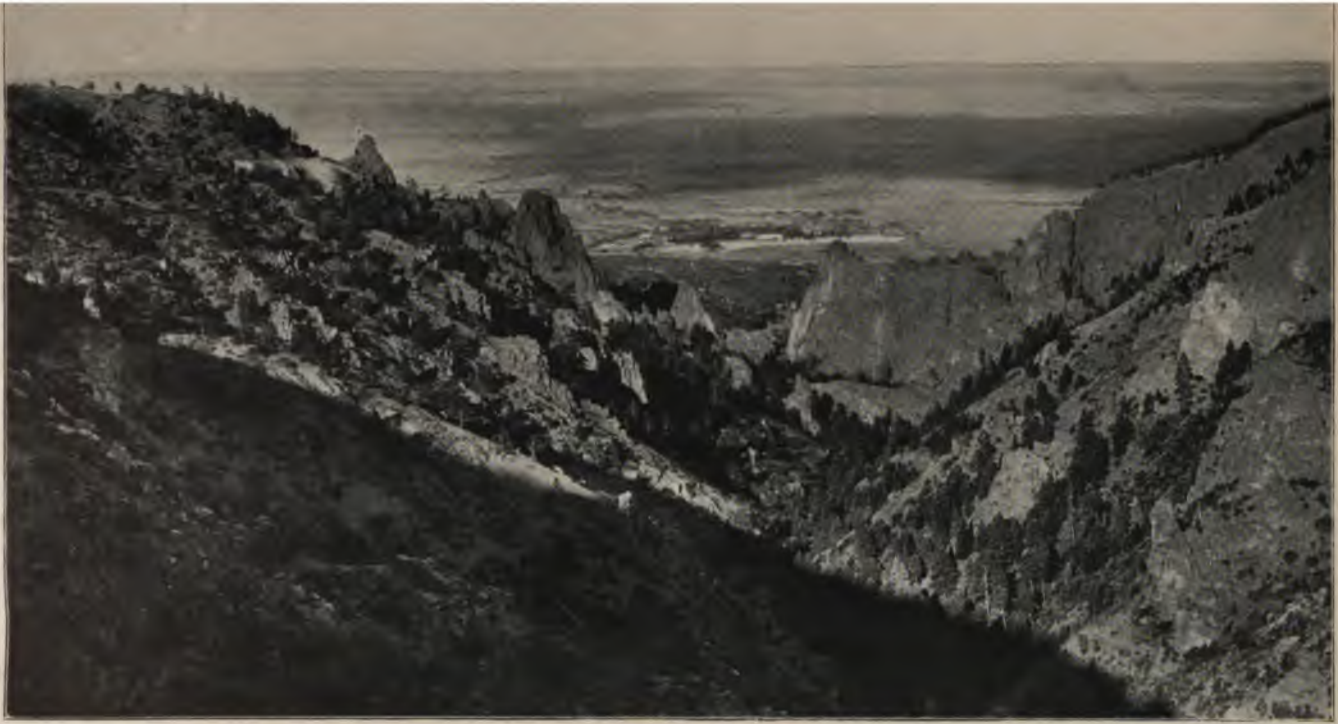

PLATE 18.—VIEW LOOKING EAST TOWARD THE PLAINS FROM WITHIN NORTH CHEYENNE CANYON.

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the mouth of the canyon shows how the moving sands in the water course have smoothed away the bed rock. The granite below the level of the water is polished as compared with the rough surfaces of rock standing above the stream where the forces of the weather attack them. Before so much cutting was accomplished the stream was working in earlier geologic days at much higher levels than those of its present bed. North Cheyenne Creek was once on a level with the highest points of rock above it. It has made a cut like a saw. Its volume in early times need not be taken as having been greater than it is at present. We have no proofs that the stream was ever much larger than it is now. It was never as wide as the top of the V-shaped canyon in which it flows. See Plates 17 and 18. The cutting accomplished by it is like the vertical line drawn from the top of the letter V to its point, and while the stream did this, small streams, coming in from either hand, the wash of water down the side slopes, and the decaying influences of the weather on the rock masses, have worn back the canyon walls. Had the rainfall all along been greater, the V-shaped valley would have had sides which sloped down to the stream much less steeply. Plate 17, at the bridge one and a half miles up the canyon, is taken at a point where the weather has been more than usually successful in wearing back the valley sides. The granite is cut up by multitudes of great cracks. Many of these are nearly vertical, and they have strongly influenced the attitude of the valley sides in making them steeper than they would have been otherwise. Plate 19.

Water requires a certain minimum slope to enable it to flow down stream in river courses. The rush of water down a mountain side is at first torrential. The slope from the head of a stream to its lower levels is then very great. As the water cuts its bed more and more by the help of the broken pieces of rock which it snatches up and uses as abrading tools, its grade, *i. e.*, the steepness of its bed, becomes less and less. As one proceeds up stream toward the Bruin Inn, the road, which follows the river grade, becomes steeper and steeper. Here waterfalls are frequently met, Plate 20, and these are in the places where the river has not as yet succeeded in cutting down some unusually hard or strong section of the granite. In time these will disappear with sufficient cutting, and the river along its whole course will flow on a very easy slope. Then it will be like a river at grade on the plains, with no waterfalls, and with no rapids. Waterfalls and rapids are temporary affairs in a river's course, to be worn away quickly, geologically speaking. The largest amount of cutting at the present stage of the work must be done along the upstream portions of the canyon. Stated in another way, the greatest opportunity for cutting is near the head waters of the stream.

The mass of the mountains would be at last completely worn down by atmospheric weathering and by the cutting of the many streams flowing out toward the plains if the process were to go on without interruption. Such, however, is not the case. Uplifting movements over certain areas within the earth are constantly taking place. They are not sudden, but very gradual, and at the same time other portions of the earth are slowly settling. Along the Atlantic coast, it is well known that the New England shores are gradually coming to stand higher out of the water. In this region the land rises with reference to the ocean. The New Jersey coast is sinking at some such rate as one foot in 100 years. The streams are always at work cutting down the mountains. They give to the mountains their sculptured forms in nearly every instance. Pike's Peak has been carved to a small extent by glaciers which once existed upon its flanks. See Excursion 7. The sculpturing on every other mountain seen from Colorado Springs was done by streams. The height of the mountains above the surrounding country is not due solely to the amount of uplift they have sustained, but to the strength of the rock composing them. They are the

PLATE 19.—ENTRANCE TO NORTH CHEYENNE CANYON.

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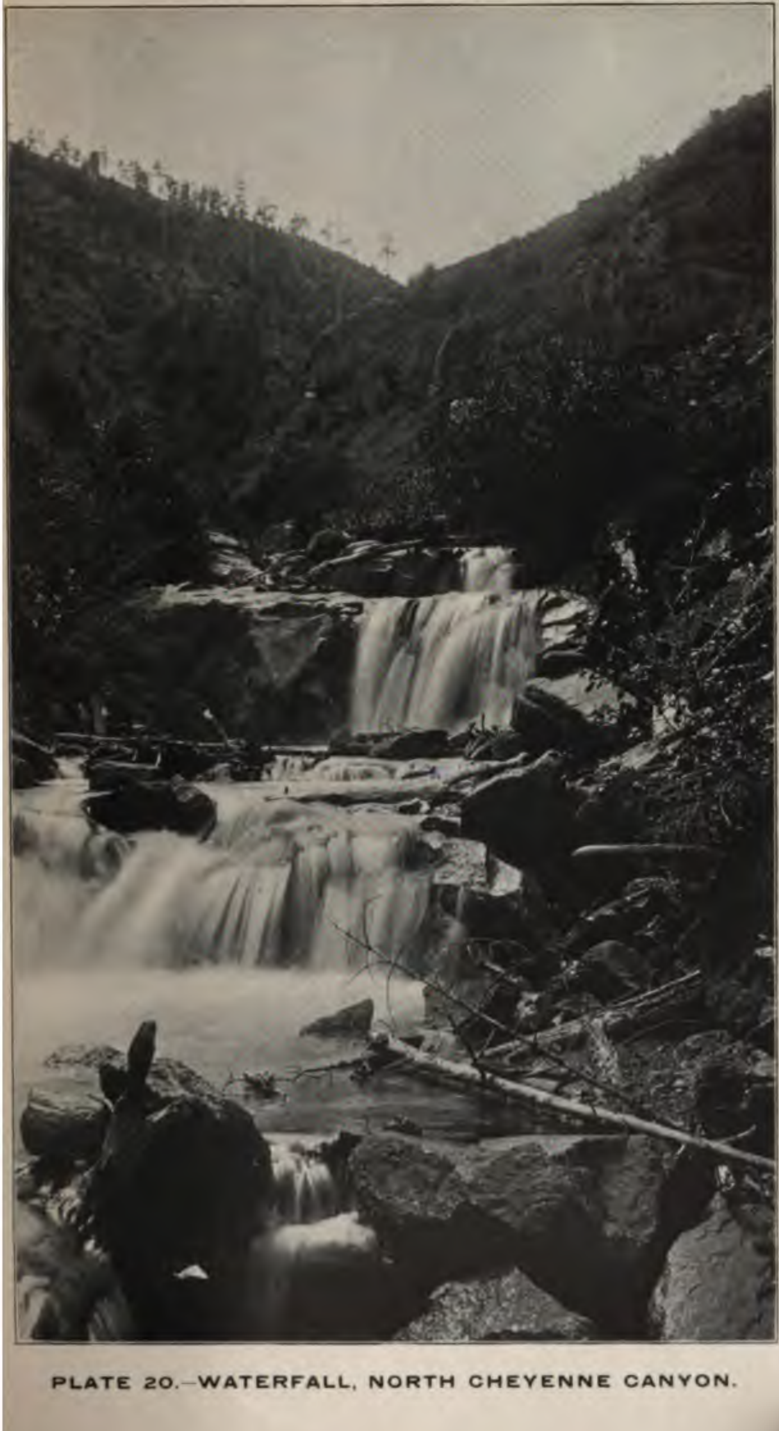

PLATE 20.—WATERFALL, NORTH CHEYENNE CANYON.

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more resistent parts of the earth's surface, and they owe their elevated position in large measure to their strength in withstanding the cutting power of streams, and in resisting the etching forces of the weather, better than surrounding weaker rocks. But mountains generally represent portions of the earth's surface which have been uplifted more than the surrounding tracts. A prime factor in the making of mountains is differential uplift. We know that the mass of Pike's Peak has been upraised more than a mile higher than that of the mountains to the north of Manitou. A break came along the Ute Pass. The rocks slipped vertically past each other, on the sides of the great fissure, and one block went up more than 7,000 feet beyond the other. This movement was not sudden; it was probably interrupted over long periods, but it is responsible, together with the strength of the granite to withstand weathering and stream erosion, for the prominence of the Pike's Peak mass over the surrounding country. In addition to this localized movement the whole Front Range itself was uplifted essentially as a unit. The name "Front Range" has been given to the range of the Rocky Mountains which borders the great plains on the west. Its height above the plains is a consequence of the strength of the granite rock composing it and the amount of uplift which it sustained. Its sculpture is a consequence of stream cutting.

Since rivers are constantly eroding their beds and making finer and finer the loose rock, gravel, and sand which they grind together, it is evident that they must have to dispose of an enormous amount of loose rock and fine sand, as well as mud. At times their courses are actually impeded to an appreciable extent with it. The material is, however, constantly journeying with the waters towards the sea. Its progress is arrested again and again. Whenever there is slack water along the river bed, some of the material is temporarily dropped, but ultimately all the fine material is borne into the sea beyond the river's mouth. Ocean currents sweep it up and down the coast and it falls to make sheets of sand, mud, or gravel, in the shallow waters off shore. This process was considered in Chapter 2. Should the whole continent in time rise higher with reference to the sea, the off-shore strip of sand or gravel will be added to the land. This happens again and again.

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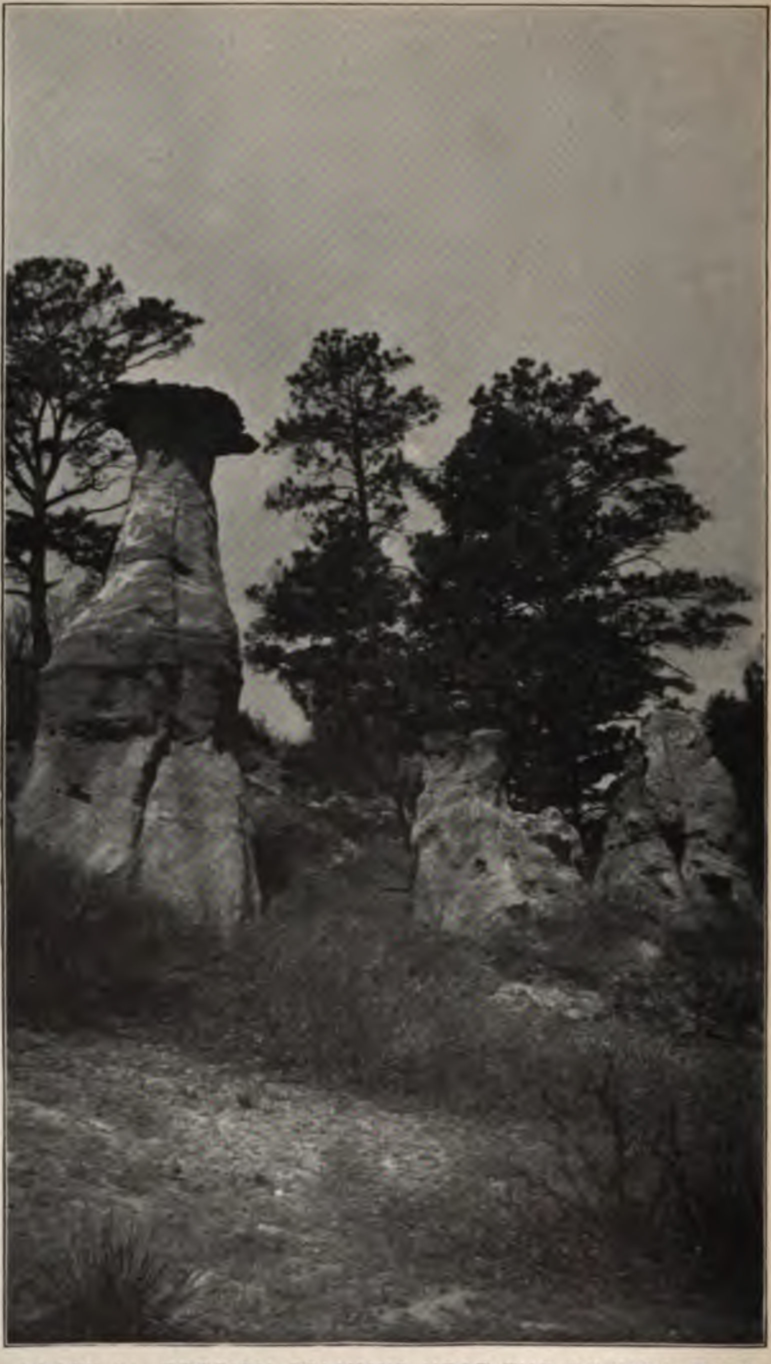

PLATE 21.—EROSION COLUMNS NEAR THE ENTRANCE TO MONUMENT PARK.

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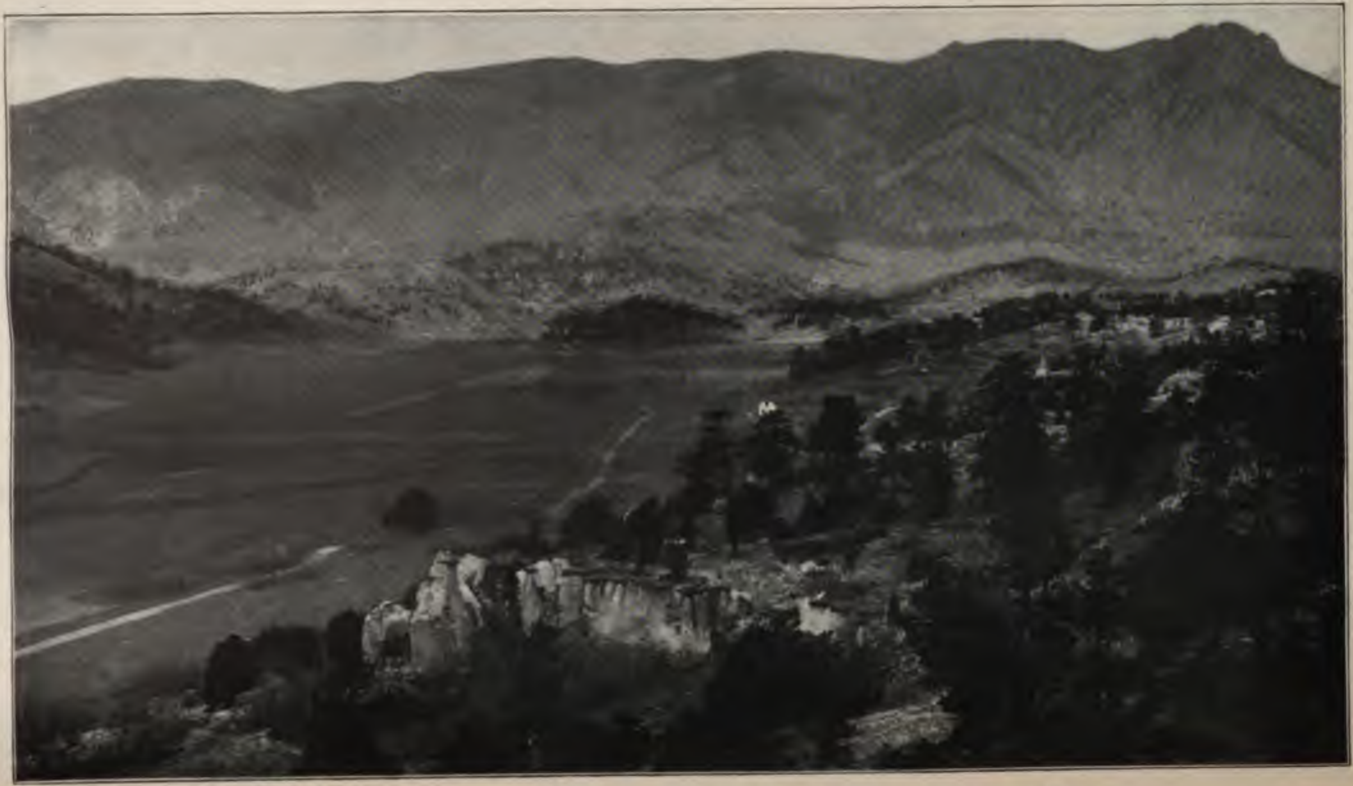

PLATE 22.—GENERAL VIEW OF MONUMENT PARK, LOOKING WEST.

Excursion 5.

The Erosion Columns of Monument Park.

THE valley known as Monument Park lies about eight miles north of Colorado Springs. It runs in an east-west direction from Monument Creek back to the mountains. The traveler may conveniently make the excursion by taking the Colorado and Southern Railroad to Breed. From this station the road leads west to Monument Creek. The old bridge at this point is broken down, but by crossing on the footway, which has been made over the creek one meets the road leading beyond the D. & R. G. R. R. track into the park. The distance from Breed station is three-quarters of a mile. As one is about to enter the park in this way one sees on one's right hand the columnar masses of rock shown in Plate 21. These singular forms are not difficult to explain. They are due to weather work on level bedded rocks of very unequal hardness. The columns are made up of conglomerate. The materials which form this rock were won by the wearing down of the granite. Quartz and feldspar are the prominent minerals which one notes in the pebbles of the conglomerate; and these, with mica, went to make up the granite before it was broken down by the weather and cut into by streams and rivers. The finely divided rock, as gravel, was swept out to sea and there deposited in layers. The sheets of pebbles were cemented together after the manner outlined on page 10, Excursion 2, and raised above water to form part of the land. The conglomerate is for the most part light colored, unlike the similar rock between Manitou and the Garden of the Gods, for the reason that but little iron, the chief coloring agent in nature, appears in the cement between the grains. Some of the layers in the series, however, have their constituent grains bound together very firmly by an iron cement in unusual abundance. These are the hard layers of which fragments appear on the tops of the columns. They are a dark, rusty brown. This cap rock was once in continuous sheets which resisted the down cutting forces of the weather very effectively. When, however, they were once broken through, the weaker conglomerate beneath them gave way very readily. They have been removed in large part over much of the park, but in the general down-wearing of the country many small patches of the hard, iron-cemented cap rock still remain. These have always saved the conglomerate beneath them from dissolution. Were the hard cap removed from the tall column, Plate 21, it would quickly be worn down to the general level. This is the condition which the two smaller columns beside the larger one have experienced. They are much reduced, but not as yet completely removed. In a very dry climate the decay of such columns, depending as it does upon moisture in the air, is slow, for the rains are infrequent, and the atmosphere is generally dry. When the rains do come they gather in swift sudden runs, and accomplish a large amount of cutting in a relatively brief time. The bases of the columns are attacked in this manner. Some are so fortunately placed as to be aside from the main courses of running water in times of rain. But when once the hard cap has been removed they quickly succumb.

With this explanation in mind the traveler should proceed along the road which follows the little depression just south of the point in Plate 21, until he comes in sight of the square stone house a quarter of a mile to the west. On turning north at this point and climbing the ridge, he will have an extensive view of the whole of the park. Forty or fifty columns are in sight. Plate 22. By taking

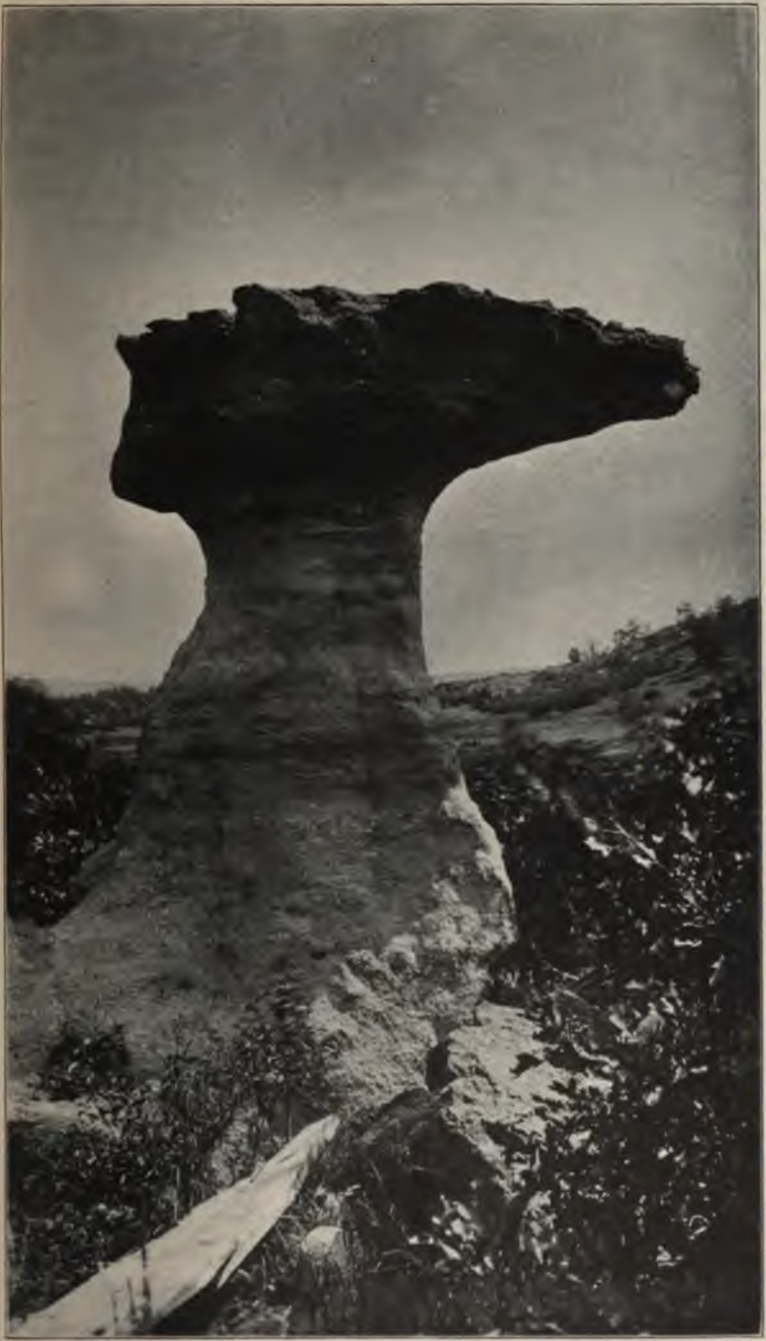

PLATE 23.—COLUMN OF ERODED CONGLOMERATE NEAR THE MIDDLE OF MONUMENT PARK.

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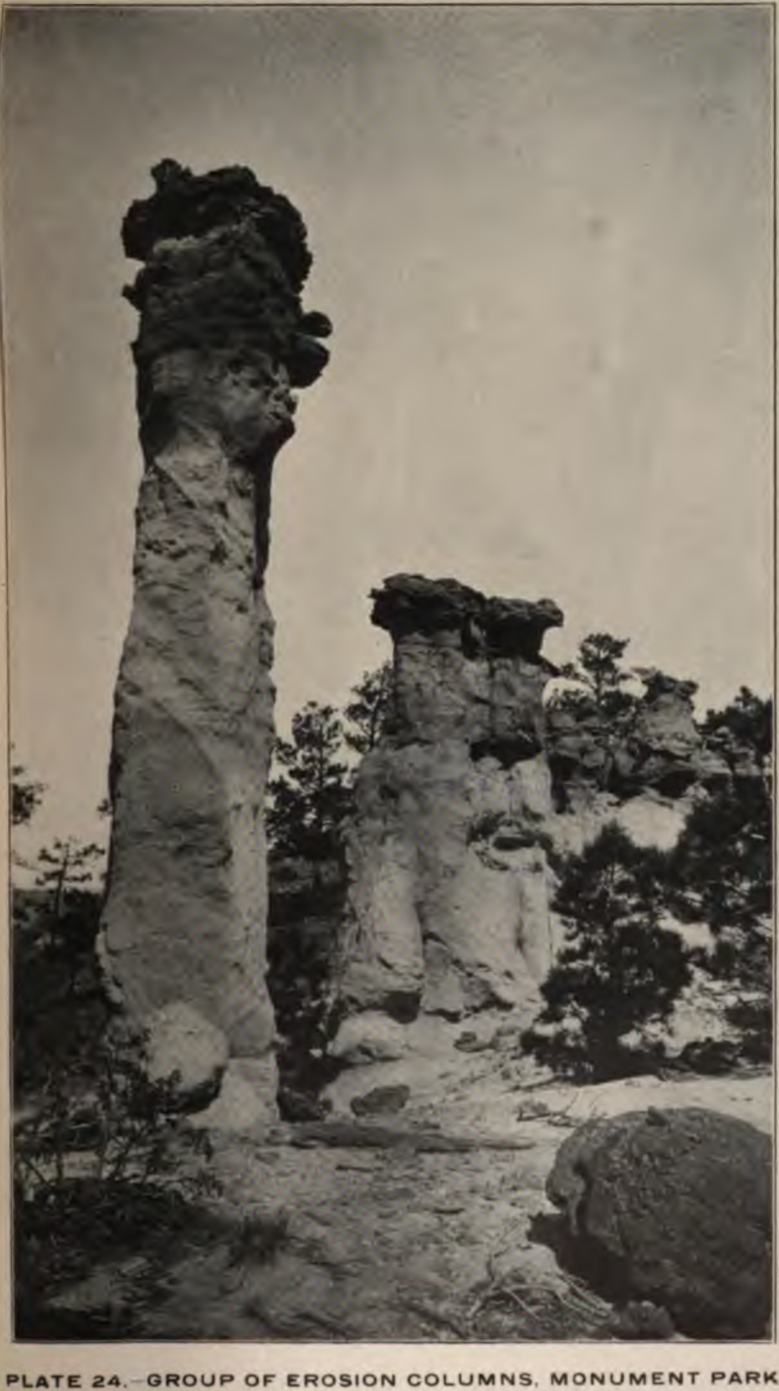

PLATE 24.—GROUP OF EROSION COLUMNS, MONUMENT PARK.

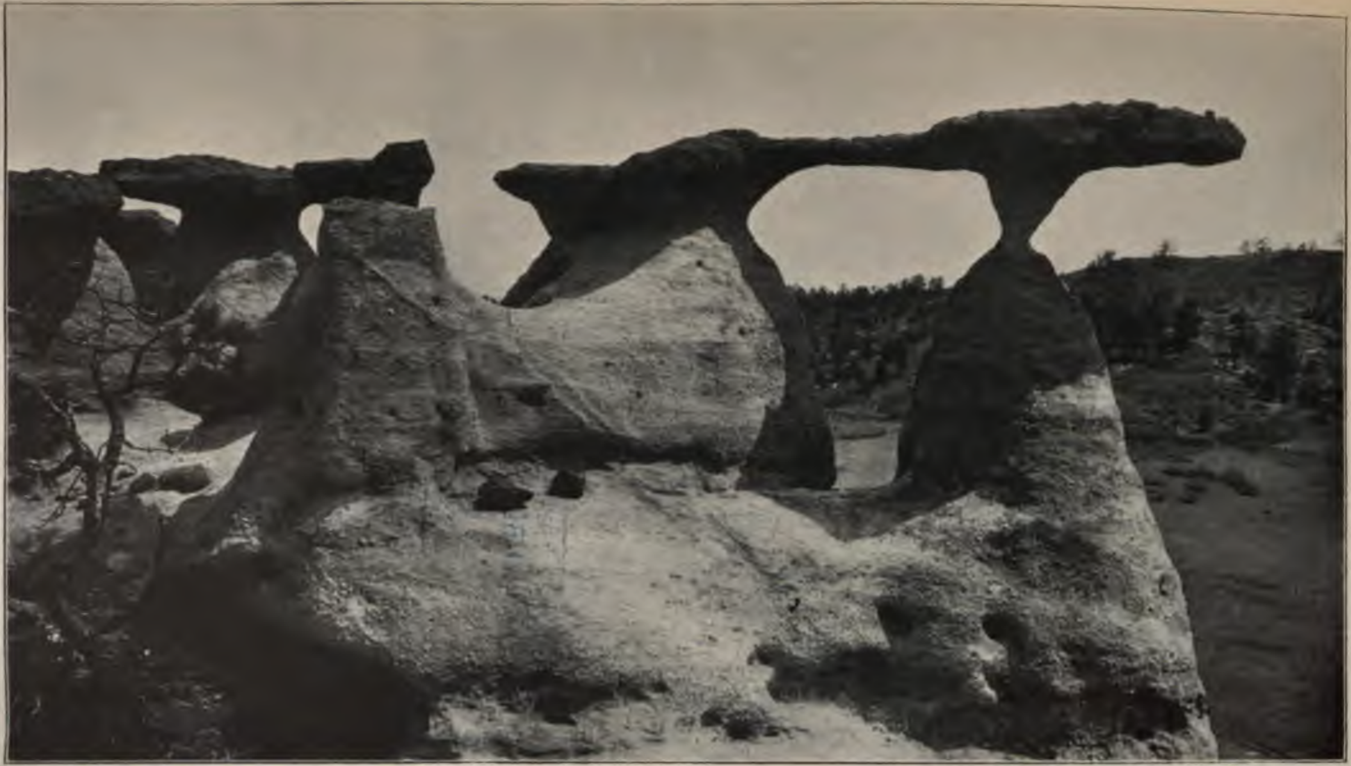

PLATE 25.—GROUP OF COLUMNS, MONUMENT PARK. THE CAP ROCK IS CONGLOMERATE CONTAINING LARGE AMOUNTS OF IRON.

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the road again, or by following the ridge parallel with it toward the west, a short walk brings one near the weathered mass of conglomerate shown in the middle ground of Plate 22. A study of this shows how the solid blocks are worn into columns in the first place. The conserving effect of the hard layer is at once apparent. Farther on along the road toward the deserted white house one meets the large column shown in Plate 23. The cap-rock upon it is massive, and it is clear that the column itself will in time be so reduced as to fail in supporting the cap. The group of columns given at the right in Plate 24 show the other condition, that where the cap is being removed first while the column of conglomerate is still big beneath it.

In walking through the park one may note that where columns stand near together on a hillside their caps fall into a common plane, as in Plate 25; and that those columns which are farther down the slope than their companions must be individually taller, to reach the layer of which their caps are fragments. It is not difficult to reconstruct in the mind's eye the whole block of conglomerate occupying the site of Monument Park. Out of it the streams have been cutting many small valleys while the weather working against the residual masses of rock in the ridges between them leaves them in companies of columns. Probably 3,000,000 years have passed by since the conglomerate was made into land to be worn down in this way.

* * *

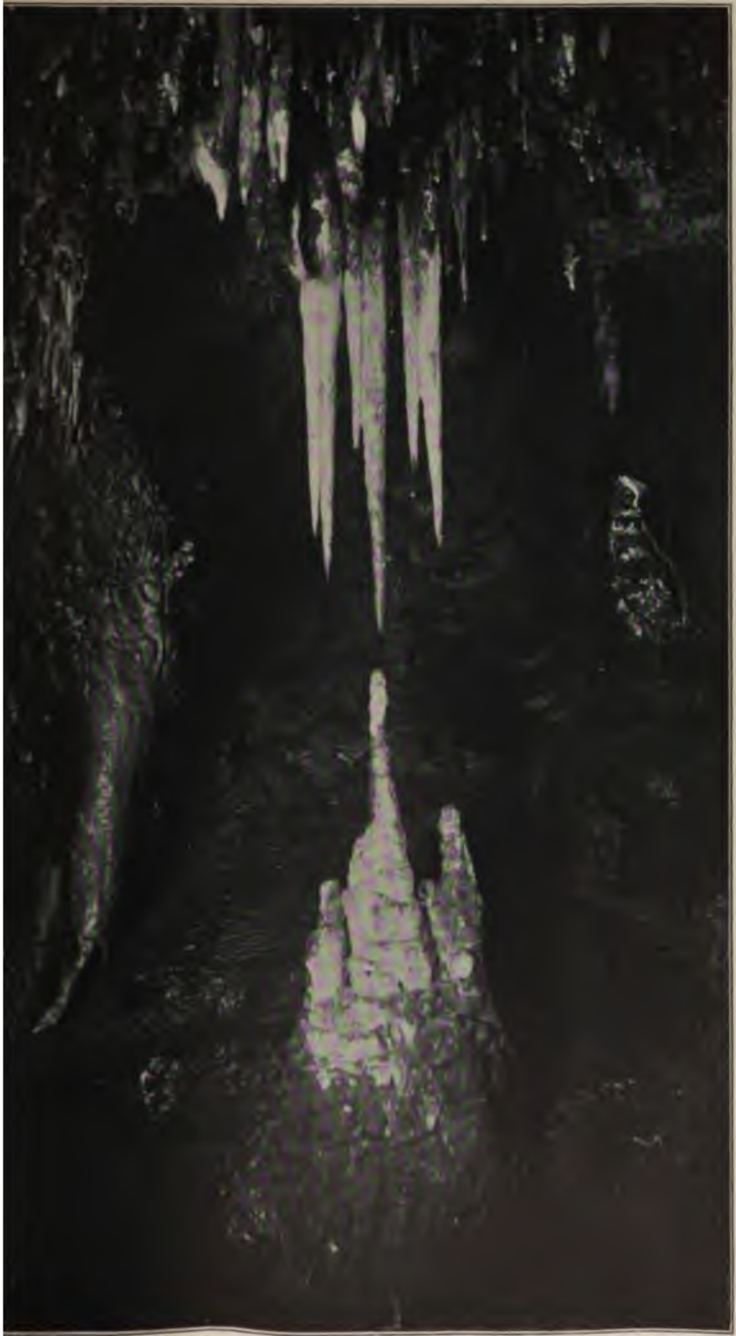
Excursion 6.

The Limestone Caverns Near Manitou.

THE limestone caverns near Manitou are much smaller, when compared with the great cave in Kentucky, but they illustrate the process of cavern making quite as fully. Certain of the formations peculiar to caves are represented in them with uncommon beauty.

As one enters the Cave of the Winds the rock on either hand has the appearance of having been in large part dissolved away. The rock mass known as the Bat's Wing, near the entrance, has a fluted surface as though water had run over it in streams and eaten into its substance. Such limestone caverns depend for their existence upon the fact that the limestone in which they stand is more easily dissolved by water passing through it than is any other rock. The limestone must lie nearly flat in thick beds if it is to lend itself to the process of cavern-making. It is not unusual, however, to have occasional thin sandstone layers in the midst of the limestones, such as that which appears along the back wall near the entrance.

When rain falls on the earth it does not all flow away in surface streams. A part of it soaks through the soil and moves for long distances under ground along the cracks in the masses of rock. It issues forth again in springs. Pure water is able to dissolve all rocks to a slight extent. Limestone is much more easily soluble than the others. As it passes through the layers of soil near the surface it encounters decaying vegetable matter and becomes charged with some of the gases incident to de-



TE 26.—STALACTITES AND STALAGMITES, CAVE OF THE WINDS, MANITOU.

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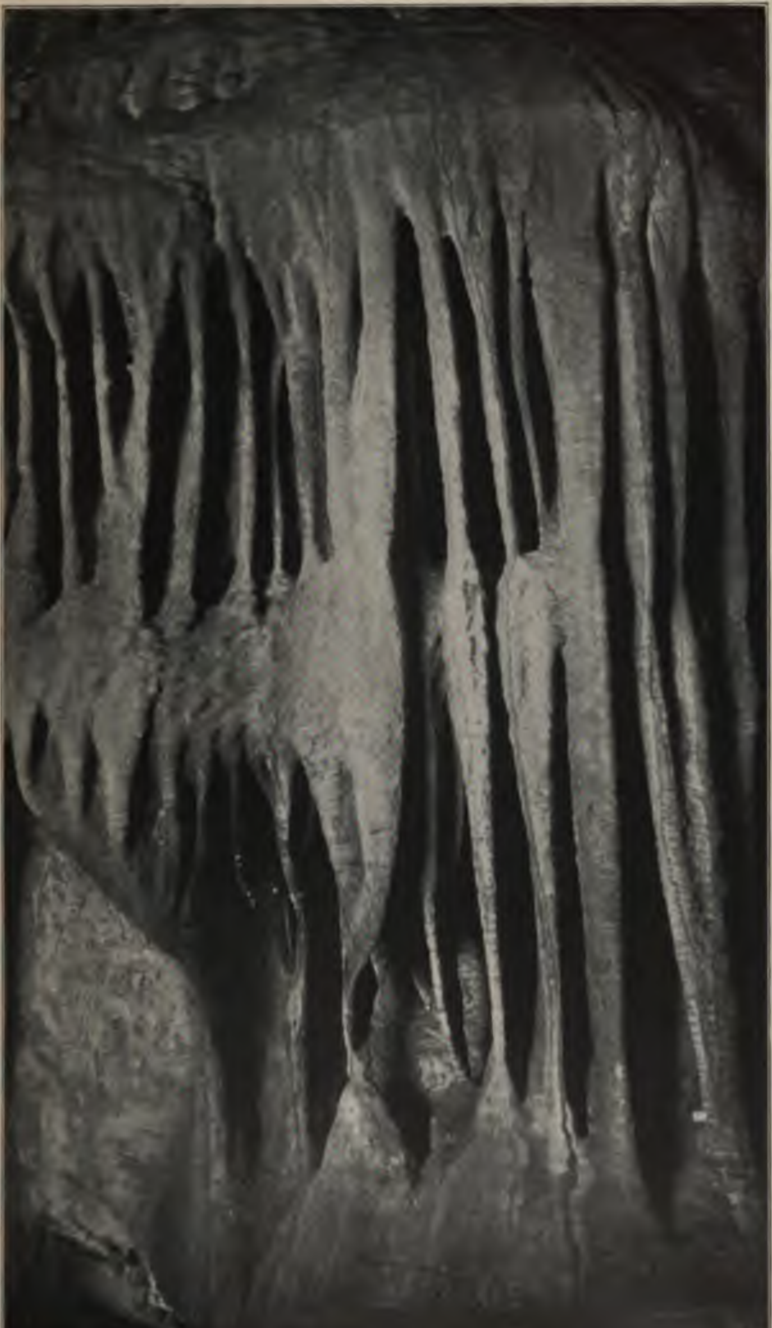

PLATE 27.—CALCITE COLUMNS FORMED BY THE UNION OF STALACTITES AND STALAGMITES, CAVE OF THE WINDS, MANITOU.

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composition. Limestone then becomes its easy prey. The waters enlarge every channel through which they pass. Rocks are full of nearly vertical cracks extending downward for hundreds of feet, and these are intersected by cross fractures running horizontally. The sets of fractures in bedded limestones are like the mortar-filled spaces in courses of brick work. Water charged with gases taken from the soil makes these fractures larger and larger in its passage. The rock within the caves is the same as that which appears in the walls of Manitou Canyon. Plates 8 and 9 serve to set before the reader the appearance of the vertical and horizontal cracks. The dark places mark the openings of small caves which in some cases extend back for many feet from the surface. In the midst of most limestones pieces of flint are found and these are only slightly soluble in water, if at all. Such flinty impurities are apparent in the limestone first encountered on taking the road into Manitou Canyon. More or less iron and alumina are present as impurities in the midst of the rock as well. All these are set free as the limestone is dissolved away. The water flowing in the stronger channels is able to take such materials and erode its bed with them as a surface stream would. Cutting in this way may go on until long deep galleries are made in the rock, the enlargements of original vertical and horizontal cracks. Sooner or later the same process advances at lower levels in the limestone and the old channel may be abandoned for an easier one below it. In this way many deserted galleries may be left at last which were original waterways in the limestone. They become filled again by quite different processes. Sometimes the amount of relatively insoluble rock particles in the stream is so great as nearly to choke its course when the waters fail as having been gradually withdrawn to lower channels. Most of the passages in the Cave of the Winds, as the guides point out, were originally in this condition. The soil on the floor of the chambers represents in large part the impurities in the limestone.

Much sand has also been washed in by the streams which plunged down the sink-holes from the surface. Many tons of sand have been carried out from the galleries to make them passable.

Cracks in the roof of a gallery are frequently marked by rows of hanging calcite icicles. These are called stalactites. Plate 26. Some are observed along the roof just inside the entrance to the Cave of the Winds. Drops of water which have come through the rock along the crack overhead have brought in solution minute amounts of the lime compound which makes up limestone. On issuing forth along the crevice overhead they evaporate quickly and give up the mineral matter held until then in solution. The stalactites are built up very slowly in concentric layers, as the mineral charged water trickles down along their outer surfaces. A stronger run of water may keep a central hollow passage open to the lowest tip of the stalactite. The rate at which the water comes from the crack overhead determines whether it will drop to the ground or evaporate on the surface of the stalactite. If it falls to the floor of the cave a mound of calcite will be built up. In time this may rise as a prominent column. These are called stalagmites. Some of the largest in the cave are those shown in Plate 26, from the Bridal Chamber. When a great deal of mineral matter is brought in solution by the water oozing along an overhead crack so that very large stalactites are formed along it, and stalagmites below them as well, solid pillars may be built from floor to roof of the cave. Plate 27. In the end these growths close up the galleries so that passage along them is no longer possible. The process is, however, extremely slow.

Immediately after passing the Bat's Wing, one turns to the right for a short distance and then resumes the original direction, passing into two small chambers on the roofs of which numbers of stalactites and curiously varied crystalline forms appear. In these chambers the dropping of mineral charged water has been very irregular. The

PLATE 28.—IRREGULAR STALAGMITIC GROWTHS, CAVE OF THE WINDS, MANITOU.

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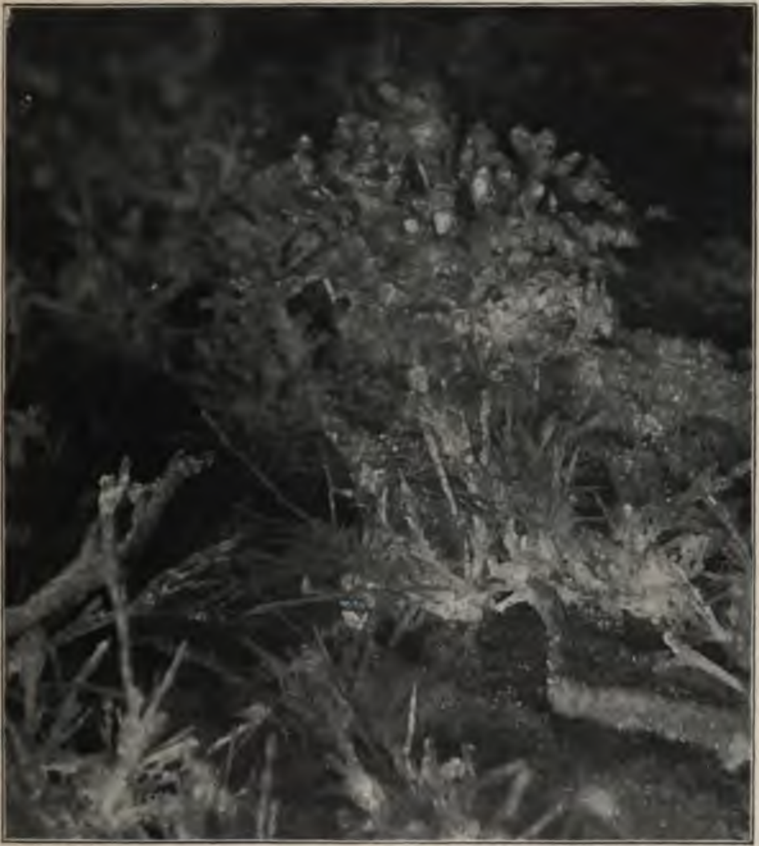

PLATE 29.—FORMS ASSUMED BY CALCITE GROWTHS ALONG ROOF OF GALLERY, CAVE OF THE WINDS, MANITOU.

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growth of stalagmite matter has been so uneven that fantastic forms of great beauty have resulted. The shelving sides of the galleries carry them as well. Plates 28 and 29.

By mounting the steps at this point, one may enter the Bridal Chamber, where some of the largest stalactites and stalagmites are seen. Plate 26. This is the best place to mark the effect of trickling waters coming down through the roof. At the present time deposition of lime carbonate is going on over the surfaces of the stalacites. One may note that many of the tubes are hollow. The main galleries were worked out by the running of underground streams almost as wide as the passages themselves.

The method by which limestone is attacked in nature might be represented experimentally by taking some hundreds of rectangular blocks of rock salt which had sand grains as an impurity all through them, and building the blocks up like brick-work layer after layer, with a few very thin sheets of loosely cemented sand between them. Water allowed to fall on the surface of the mass would make its way down along the vertical spaces between the blocks, dissolving the walls and so enlarging the passages. The water would carry along all the sand grains that were dissolved out of the salt, and use them to abrade the channel ways. The downward passage of the tiny streams would be stopped for a long time by each successive layer of cemented sand grains. The water would flow off horizontally over them, but in time they too might be broken through in places and the process begun lower down with the desertion of the upper galleries for newer ones. Water in its passage down into the mass of rock salt would leave vertical funnel-like openings leading into the mass from the surface. We see just such funnels in limestone regions where caverns are abundant; they are known as sink-holes. The steps leading up to the Cave of the Winds from Manitou Canyon are built inside of such a sink-hole ten or fifteen feet in diameter, its walls in places broken away, down which the water plunged in former times.

After the caverns had been formed in the Manitou Canyon limestone, Manitou Canyon itself was made by the cutting action of the streams following the direction which the canyon takes. It is probable that in the making of the canyon caves comparable in size with the Cave of the Winds were destroyed.

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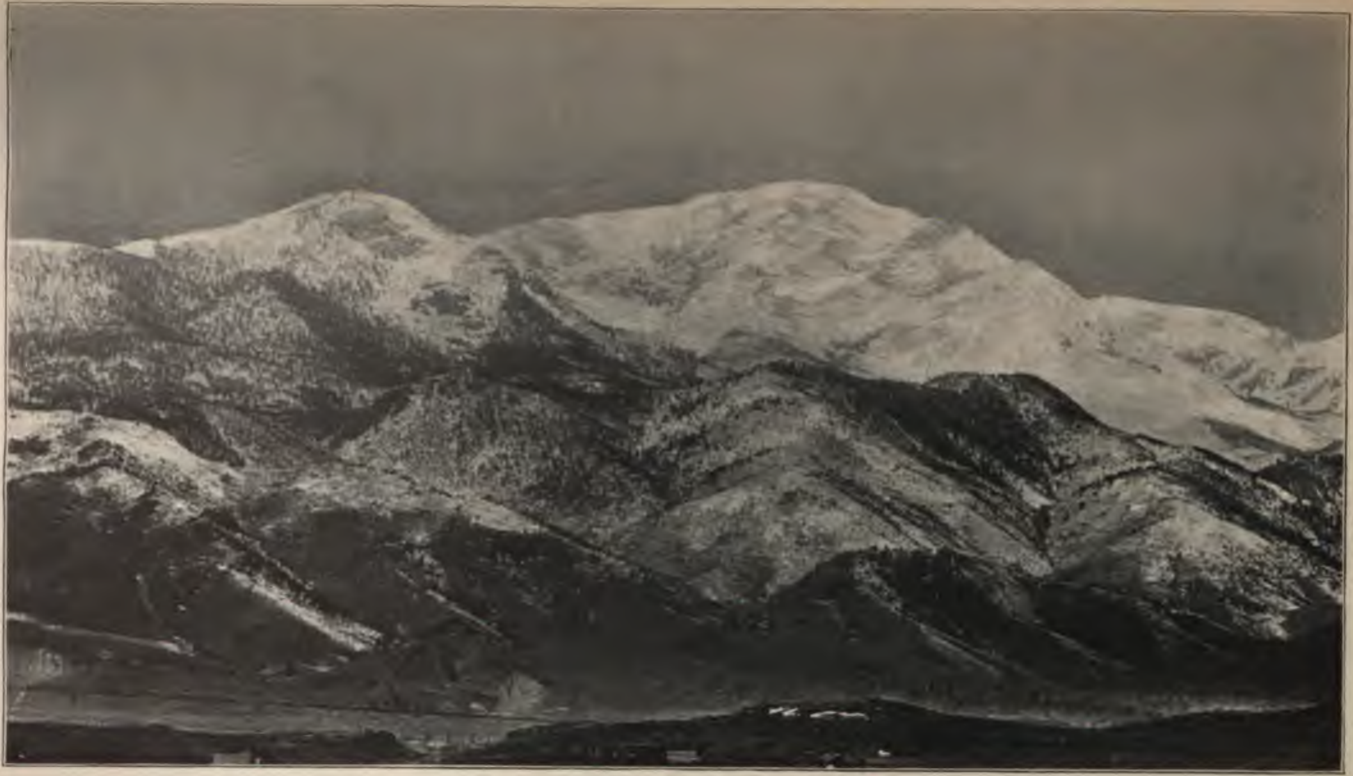

PLATE 30.—PIKE'S PEAK FROM COLORADO SPRINGS.

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Excursion 7.

Pike's Peak.

PIKE'S PEAK is interesting because of its peculiarly sculptured flanks. The same forces that have carved the Matterhorn have been active against it. The forces of erosion, decay under the weather, frost riving, and stream cutting are everywhere operative. On the highest mountains we may have the cutting done by glaciers. On Pike's Peak five or six glaciers were active in former days.

Glaciers are the result of climatic conditions which make for an excess of snowfall over snow waste. More snow must fall during the winter season than can be carried away by the succeeding summer heat. This banking up on the mountain of snow that does not go away from year to year, leads to the production of ice in the deeper ravines near the summit. The crystalline snow flakes are pressed together by the weight of the overlying layers of snow and they become, lower down, crystalline ice granules. At the bottom of the pile they are firm crystalline ice. Gravity is responsible for this condensation. The granules by the weight upon them are made to melt where their parts touch, and the resulting moisture at once freezes in the open spaces where the rounded grains of ice are not in contact. Each grain is very slowly readjusting itself to the stress upon it as the layers above bear down with their weight. The grains move by minute amounts, and the sum of all these movements is the slow thrusting forward of the whole ice mass down the valley. The glacier moves at some such rate as 3 or 4 inches a day, more in summer, less in winter. By the movement of the stream of ice down the valley to the point where evaporation at a lower level reduces it to nothing, compensation is made for the excess of snow fall over snow waste in the snow fields high up on the mountain.

There have been no glaciers on Pike's Peak for thousands of years, but the hollows in which they lay are so peculiar that they are unmistakable. There are five of these on Pike's Peak. One is very plainly in sight from Colorado Springs, the cup-like hollow depression just between Cameron Cone and the summit of Pike's Peak. Plate 30. It is known as the Crater, but has, of course, nothing to do with volcanic activity. A glacier does not scrape away much of the bed rock under it, though it makes it relatively smooth by rubbing over it with the small pieces of rock frozen into its under surface. It rubs against its valley sides and scrapes away much broken-up rock which it proceeds to carry along its flanks, as it moves slowly down the valley. When at last by climatic changes over the country the glacier is entirely melted away these accumulations of broken rock along its former course are left to mark the width of the glacier from side to side. They are called the lateral moraines. Very good lateral moraines may be seen on either hand to the north and south of Lake Moraine. The ridge bordering the lake on the north and 25 feet above it is very nearly perfect. That which rests against the flank of Bald Mountain, along the south shore, is less prominent, but its level top line is still very distinct. The hollow in which the lake rests was made by additional accumulations at its foot, that is, to the east of it. This was the point beyond which the glacier did not go in its movement down the valley. All the loose stony material which it carried was left at that point as a terminal moraine. The embankment has been made stronger by an artificial dam. Such lakes are common in mountainous districts where glaciers formerly existed. The ice stream which ended at the point now occupied by Lake Moraine must have been a mile and a half long, stretching down from the bounding

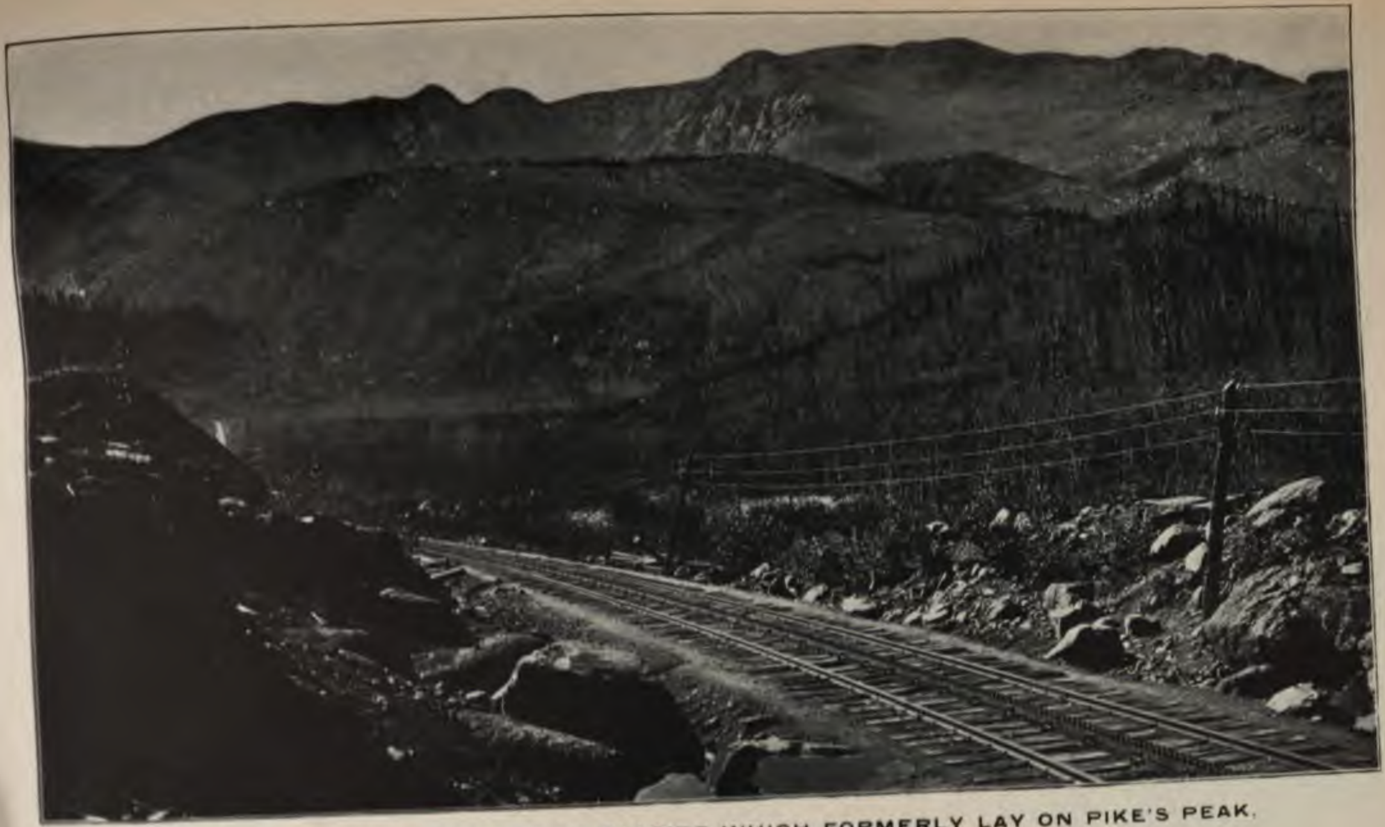

PLATE 31.—MORAINE AT FOOT OF GLACIER WHICH FORMERLY LAY ON PIKE'S PEAK.

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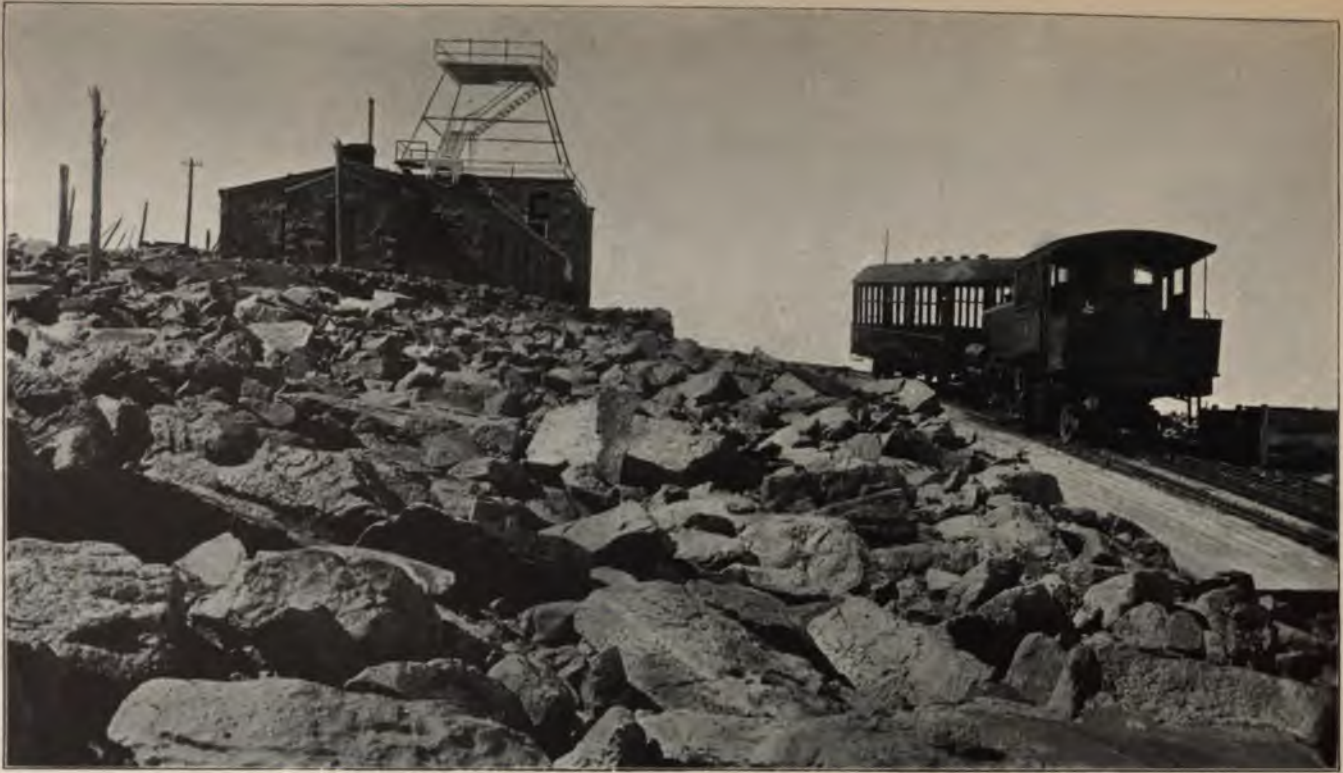

PLATE 32.—WEATHERED FROST-RIVEN GRANITE, SUMMIT OF PIKE'S PEAK.

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wall of granite to the northwest. The wall of the Crater, near the summit of Pike's Peak, is of the same kind. Such high, steep, cliff-like faces of rock are rare in nature. They indicate the peculiar cutting work which a glacier does at its head where it rests against the rock at its highest point. The nature of this work may be brought to mind by the terms of a simple experiment. When a building stone is to be tested to see how it will endure the weather, it is soaked in water until its pores have taken up all they will hold. Some porous rocks will take up water to the amount of 15 per cent. of their volume. The wet rock is put into an ice house where the temperature is low enough to cause freezing during the night. Next day the block is thawed out, and the process repeated. After a month of this the stone shows signs of wear because the water freezing in its cracks must expand and will wedge away little surface pieces. This is a severe test but it represents exactly what goes on around the head of a glacier. In summer time a portion of the ice melts against the rock walls and all the porous places of the rock are soaked with water. At night this water freezes and the result is the plucking off of pieces of the rock. Weathering of this kind is sharply localized, and very vigorous. The process is kept up for thousands of years so that it leads to very considerable digging in on the part of the glacier head against the rock. It is at the same time like a process of sapping, for the unsupported rock above will fall down upon the glacier. If, as so often happens, the rock is all broken up to begin with by great vertical cracks, a sheer wall above the head of the glacier will result. The observer standing near the summit on Pike's Peak may look down into the Crater and see how well the glacier that occupied it has succeeded in gnawing into the mountain, and removing the portions of the cliff which fell continually upon the ice as their supports were cut away below them. A short distance down toward the east is the great heap of loose rock, the terminal moraine, marking the foot of the glacier, and representing this material. This moraine is the mound in plate 31, an inch and a half above the point where the cog-road passes out of sight on the left. Five other cup-like depressions with sheer bounding walls appear on the flanks of the mountain. The Bottomless Pit is one of these. The valleys which have been occupied by glaciers are U-shaped in cross section.

The top of Pike's Peak is in a realm by itself as regards the form of erosion which weathering accomplishes upon it. Here the riving action of frost is the most important process accounting for the breaking up of rock. The temperature on the peak is often in winter and at night much below the freezing point. In summer and by day it is usually not far above freezing. There is no vegetation to furnish by its decomposition the acids on which the solvent power of water so largely depends. Under these conditions chemical decay is but slight. Weathering here proceeds by frost riving, the freezing of water at night in the pores of the rocks after a time of thawing by day. The granite blocks by this process are simply riven apart. The top of the peak is everywhere strewn with the resulting scales and broken pieces of granite. Plate 32. One sees nothing else until one gets down on the slopes where running water and chemical decay are effective.

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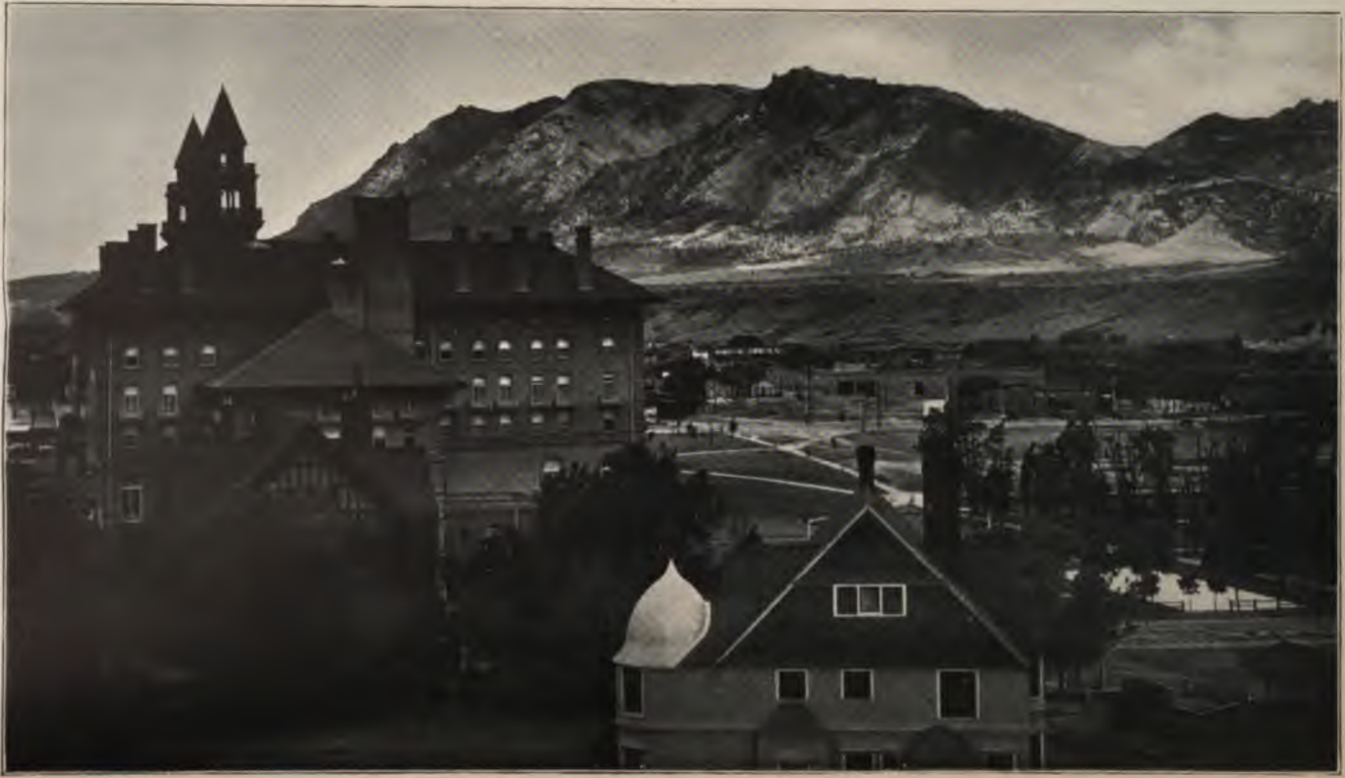

PLATE 33.—CHEYENNE MOUNTAIN.

Excursion 8.

Cheyenne Mountain.

THE road which leaves the end of the car-line at Broadmoor goes westwardly until it turns at the first house on the left and makes directly up over the mantle of gravel at the foot of Cheyenne Mountain. When it is a third of the way up the slope it proceeds on the level toward the head of South Cheyenne Canyon. The trail to the summit starts beside the little streamway which the road crosses on the western flank of the mountain.

Many small streams, which are not constant, but only torrent ways in times of rain, have been at work along the face of the Front Range in Colorado tearing into the mountains. Cheyenne Mountain, Plate 33, is seen to be deeply scored in this way. There is a great depression just beyond the horn, to the south, due to the cutting of torrential streams. The process has been going on for at least 200,000 years and all that running water has been taking from the mountains has been dropped where the rivers come out on the plains. The lower slopes of the mountains are fringed with sheets of gravel from 15 to 75 feet thick. The little torrential streams which do not rise far back in the mountains have all along been making this outwash plain of gravel. The stronger streams on the other hand, such as North Cheyenne Creek, coming from far back in the mountains have kept their courses clear of gravel, or they have been able to cut down through it. In this way the apron of gravel is so discontinuous that only slices of it are seen between the strong streams, as on

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NOTE.—The original name for "Glen Eyrie Creek" is "Camp Creek."

either hand of Fountain Creek, Cheyenne Creek, and Bear Creek. Broadmoor is built on a remnant of the great sloping gravel plain, and in Plates 34 and 35 one may notice how much of it Camp Creek has cut away.* In Plate 35, at the extreme right in the distance, the sky line is a part of the great mesa of gravel which stretches from a point near the Garden of the Gods to Colorado Springs. The cultivated low ground to the east of the prominent ridge in the picture lies along Camp Creek, and its level, so far below that of the mesa, gives us the measure of the cutting which the stream has done. The course of Camp Creek, in Plate 34 from right to left, is marked by the line of trees in the middle of the picture. Beyond the river a small remnant of the gravel plain shows on the extreme left. Its long level top is just at the right height to fall in with the line of the mesa at the extreme right of Plate 35. The two are parts of the same plain of gravel and they were once continuous.

As one proceeds from Broadmoor along the road toward Cheyenne Mountain the grade becomes steeper and the fragments in the gravel are on the average larger because the heavier pieces do not travel far along the water courses. Large blocks like those shown in Plate 16 beside Cheyenne Creek which break away from the cliff faces rarely get far from them.

Where the road first touches the bed rock, (near the telegraph pole numbered 272 at this writing), the granite is stained a deep red by iron and it appears much darker than it does higher up. A striking feature of the granite at this point is the way in which its surface is pitted by the removal of the mica which the weather has eaten away. Thousands of cracks cut across the granite in many directions. Some which are very prominent are nearly horizontal, and run for hundreds of feet continuously. Such are those shown in Plate 19. The granite is much decayed.

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*NOTE. The proper name for the creek commonly known as Glen Eyrie Creek is Camp Creek.

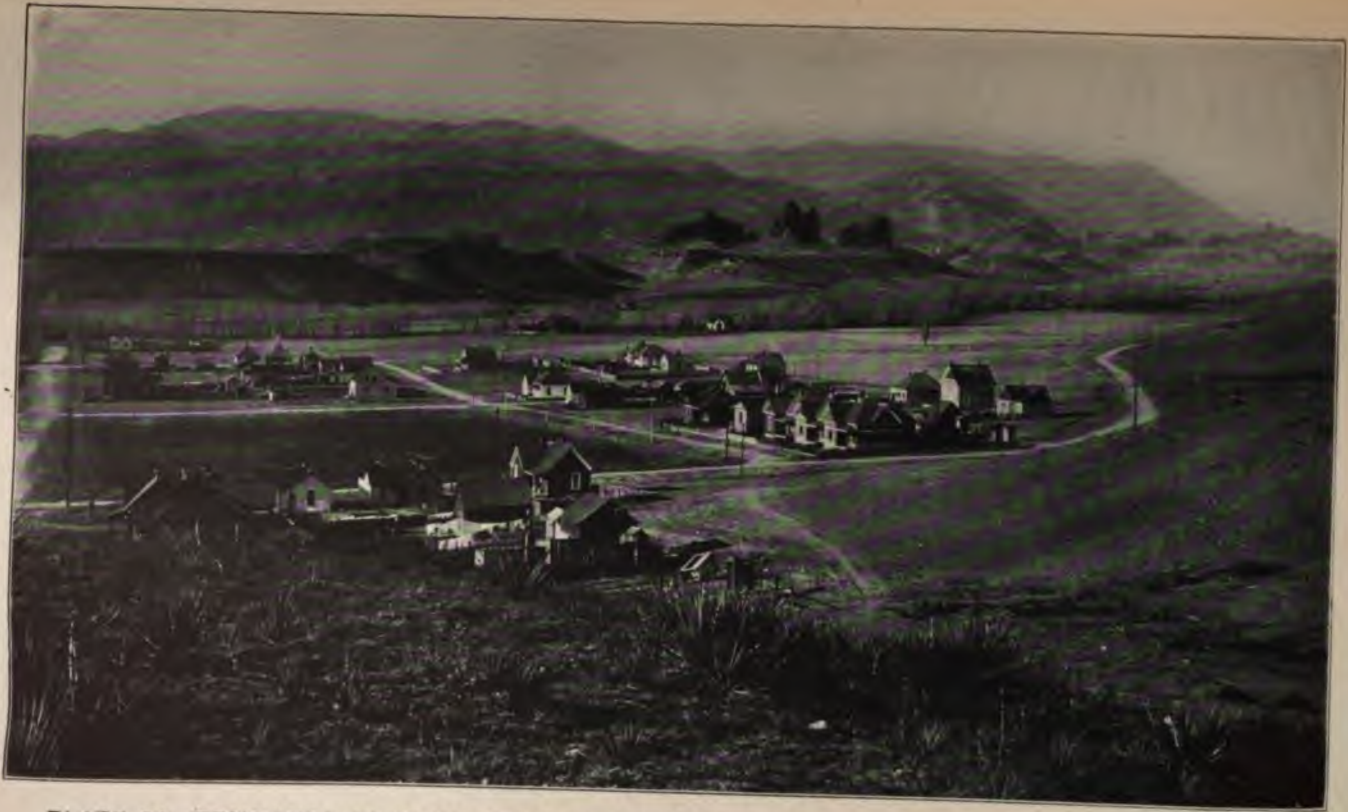

PLATE 34.—REMNANTS OF PLAIN OF MESA GRAVELS ALONG THE WEST BANK OF CAMP CREEK, COLORADO CITY.

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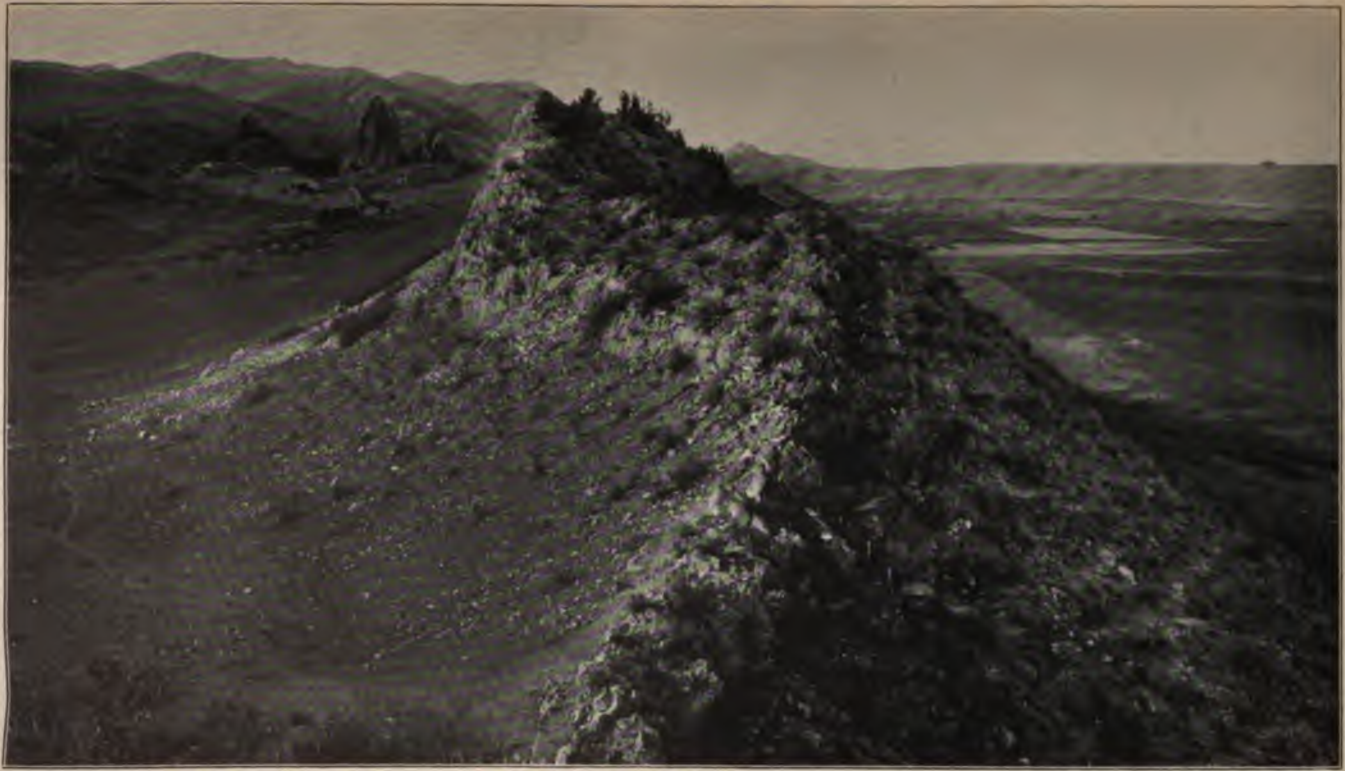

PLATE 35.—RIDGE OF SANDSTONE (CREST) AND OF LIMESTONE (RIGHT HAND SLOPE) NEAR COLORADO CITY, WHERE CAMP CREEK MEETS FOUNTAIN CREEK. MESA GRAVELS AT EXTREME RIGHT, SKY LINE.

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and the stronger portions stand out boldly in forms like those that appear in Plate 18. These columnar masses of granite are due to some peculiarity in the constitution of the rock which renders it a less easy prey to the weather. Or they may happen to be in favored places. Until stream work has operated for a long time the streams will not have succeeded in reaching every corner of the ground. The spaces between streams may be free from their attack for a long time after the country surrounding the streams themselves is generally worn down.

When one has followed the road around the northern slope of the mountain into South Cheyenne Canyon one comes at the first little stream to the beginning of the trail to the summit. This is near the telegraph pole numbered 302. On the way up one passes enormous rounded masses of granite resting in heaps one above another. They are like the blocks shown in Plate 3, but at one point they are so numerous that they quite cover the mountain.

The bold front of Cheyenne Mountain is a consequence of differential uplift. The break in the earth's crust which the Ute Pass follows, runs along the flank of Cheyenne Mountain. Pike's Peak, Cheyenne Mountain, and all between, are in the block upraised along the fissure. The ancient sea in which the sediments now making up the plains were laid down, came up to the base of the mountain. It is as though the observer standing on the top of Cheyenne were looking from the original land mass out over the sea which covered the interior of North America.

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Excursion 9.

On the Meaning of Fossils, With an Account of the Localities Where They May Be Found.

ROCK strata are the pages in the book of the earth's geological history. They were deposited in order one above another like the leaves of a book lying flat. The succession of living forms on the earth has been from first to last in a definite progression. As we examine the rocks for traces of living things, going upward into the beds of more recent age, the higher animal types appear successively. From Cambrian to recent times there are 13 divisions in the geological scale. See table on page 58, column 1. No forms higher than the fishes were known in the second of these, the Ordovician period. In the fifth, the Carboniferous, amphibia had come in for the first time in the earth's history. The reptiles were established in the next period. The earliest birds made their appearance in the seventh time division, the Jurassic. Finally, in the eighth and ninth periods, the Cretaceous and Eocene, mammals appeared and took a dominant place. Fossils are of extraordinary interest therefore, because, as they succeed one another, they give us the historic succession of animal life on the earth. Certain forms definitely characterize certain strata. They are in series like the numbers of the pages in a book. As we can tell the relative position of a single leaf by its number, and by the writing upon it, so in the same manner fossils mark the relative position with reference to the others of any stratum of rock in which they are found. In the Colorado Springs region the most recent fossil is the tooth

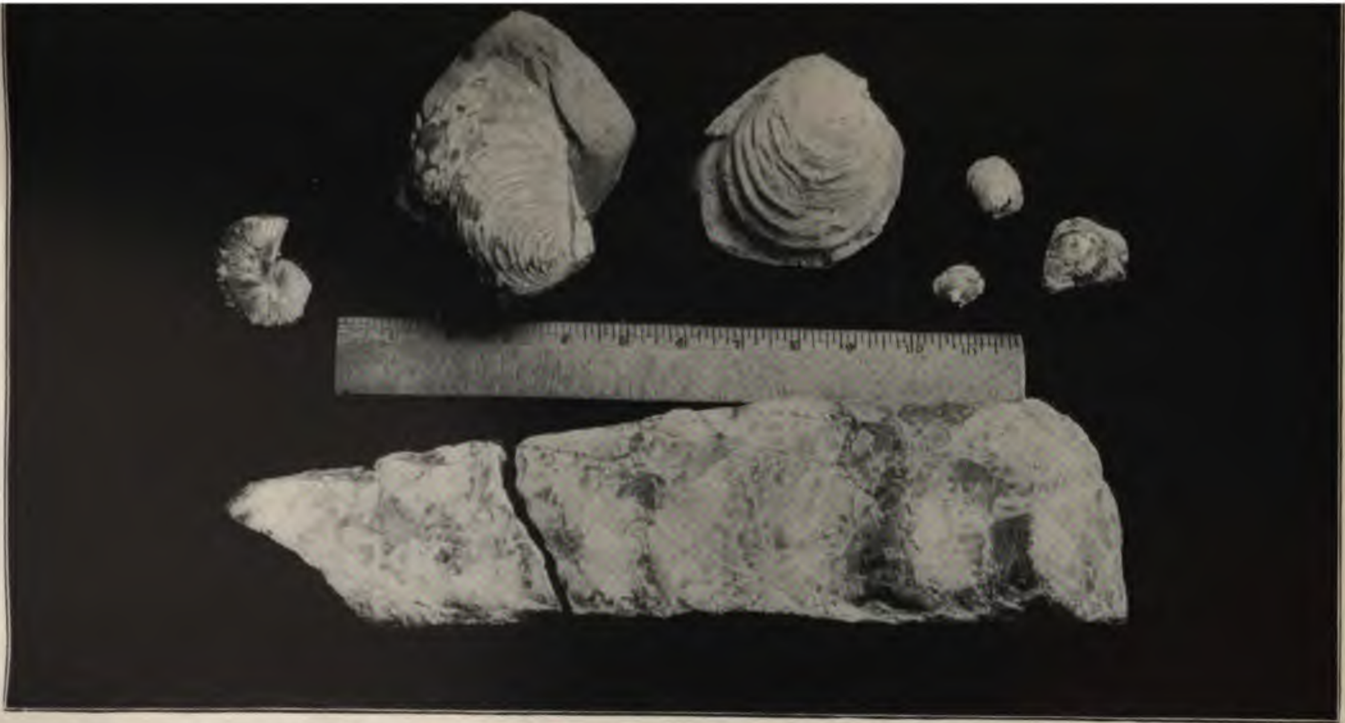

PLATE 36.—FOSSILS FOUND NEAR COLORADO SPRINGS. ABOVE RULER, LEFT TO RIGHT (1), SCAPHITES NODOSUS; (2), INOCERAMUS FROM PIERRE SHALE; (3), INOCERAMUS DEFORMIS FROM NIOBRARA LIMESTONE; (4), SMALL SHELLS AT RIGHT, LUCINA OCCIDENTALIS. BELOW RULER BACULITES COMPRESSUS.

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of the mastodon which was found buried in the mesa gravels north of Colorado City. The mastodon was the forerunner of the elephant. It has been extinct for at least 150,000 years. A quarter of a mile south of the gateway to the Garden of the Gods a few bones may be seen in the sandstone, parts of the skeleton of a Jurassic reptile which lived millions of years back. Fossil bones of this kind are extremely rare. In the Jurassic shale east of the band of white gypsum a skeleton of the reptile described under the name Mosasaurus Manitouensis was discovered in the early 80's. It is now in the museum of the Philadelphia Academy of Sciences.

In the old seas in which the sandstones, shales, and limestones were deposited innumerable shell-fish lived on the bottom. Their hard parts were often ground to pieces in the wash of the waves and currents and lost. This happened in nearly all cases when the animals lived near the shore-line, where waves are most active. But in deeper quieter water shells are often perfectly preserved in the midst of layers of mud or sand, afterwards made into beds of rock. There are usually small differences between successive layers, so that the layer on which the shell falls is slightly hardened before the next covering layer is deposited. The two layers may afterwards as solid rock be split apart with comparative ease and the fossil shell exposed. Often the original shell substance is entirely gone, but a print of its parts remains in the rock where the shell rested against materials that were once soft.

Fossil remains of these classes of animals are to be found at many places in the Colorado Springs region. It happens but rarely that sedimentary rocks appear upside down upon each other. There are no such overturns near Colorado Springs, although the layers of rock have often been thrust up until they stand vertically. Those nearest the mountains are the oldest, and the younger and younger layers appear successively as one goes out from the mountains toward the east. Geologists have been busy for over a hundred years studying the succession of fossils from older to younger layers of rock, being able to say safely all the while that the fossils in one bed lying over another are types which lived on the earth later than those in the bed below. Many thousands of species have been collected, following each other in the same order, at many different localities, until by a comparison with this series the fossils occurring in a given rock fix its place in the geological time scale. Near Manitou fossils are not hard to find in the red limestones 35 feet above the granite, either along the Ute Pass, near the Grand Caverns, or in Manitou Canyon just upstream from the Narrows. They prove the Cambrian age of the beds lying just above the granite. They are little shells not much over an eighth of an inch across and nearly round. Their white surfaces are conspicuous when they are uncovered in the midst of the red limestones which contain them. The rock is hard and a good deal of it must be broken up with the hammer before shells are laid bare. In Cambrian days no forms of life had appeared as highly developed as the fishes. Ordovician fossils may be found in the limestone layers at various levels until one is 75 feet above the road in Manitou Canyon at the point where a path leads over rock slide from the Narrows to the mouth of Hucacode Cave. The more granular layers are the most favorable ones to examine. Sections of shells like a snail's show best on rock surfaces which have long been exposed to the weather.

For hundreds of feet upwards in the series going outward from Manitou the rocks are nearly bare of fossils. A favorable place to search is on the face of the ridge just west of the United States Refining and Reduction Company's mill. The gray limestone layers at this point are nearly a foot in thickness, in prominent beds. They stand almost on end. The fossils are large shells about the size of a horseshoe. Their substance is over an eighth of an inch in thickness, and their surface when exposed, is seen covered with concentric ribs. They are known by the name

Inoceramus deformis. Plate 36, Fig. 1. They characterize the Niobrara limestone in the Cretaceous. Other shells of the same genus but smaller species are found in the overlying shales. Fig. 1 a. Along the bed of Monument Creek, which lies on the Pierre shale, small white shells an inch across occur. They closely resemble very small clam shells. Their name is Lucina occidentalis. Fig. 2. The coiled shell Scaphites, Fig. 3, is found much more rarely in the Pierre shale. It shows not infrequently a pearly surface. Southeast of Colorado Springs, near the Printers' Home, in the layers of rusty yellow sandstone exposed along the street where the Nob Hill car turns north on leaving E. Pike's Peak Avenue, and one block west of the building, small Inoceramus shells are found. They are like the large Inoceramus deformis, except for their size, and their surfaces are marked in the same way. Baculites compressus, Fig. 4, is often found in the Pierre shale. Thus far the occurrence of fossils which were originally covered up in the layers of shell fragments or mud on the sea floor have been described. It is more difficult to find the stems and leaves of plants which fell in bodies of fresh water on the land. In the fine grained sandstones making the high ground known as Austin's Bluff near the base of the cliff, leaves of trees resembling the willow are found on breaking up a good deal of the sandstone. Palm leaves in the same rock have been discovered occasionally in times past. Along the slope, under Castle Rock, near the Pikeview station of the D. and R. G. R. R., where the hard white sandstone cliff ends, and the slope of soft green crumbling sandstone comes in immediately below, there is a dark brown layer in which leaves may readily be found. Still more favorable places for collecting fern leaves are the abandoned inclined tunnel-like openings across the river east of Pikeview which were made in prospecting for coal. The layer which usually contains coal has been opened up. Above it comes a fine grained soft clay, and in pieces taken from the roofs at the tunnel entrances there is always a good chance of finding the leaves of plants.

The evidence given by geology shows that life on the earth has been continuous since its dawn. The succession from generation to generation has been without a break. The forms of living things have been incessantly changing as the creatures gathered experience from their surroundings. Some of the very lowest forms of life have lived on continuously and without any significant changes of structure in the great number of their descendants. Others of their descendants, however, have evolved forms more highly organized than they themselves were, by countless gradual changes and by more sudden departures. Water at 100 degrees F. is a liquid. A fall in temperature degree after degree in no way affects its condition as water until one passes the 32 degree point. Then an extremely slight lowering of the temperature makes a solid of water. Ice is a body with totally different properties from water. In the same kind the change from water to steam just as the temperature at sea level passes the 212 degree F. point upward results in a product utterly unlike the original. Some such transmutations are believed to occur in the animal kingdom. Today we find persisting some of the original types of life side by side with thousands of lines of their greatly modified descendants. Tens of millions of individuals have died by the way as their necessary function in the process of evolving higher forms. Whole tribes of animals have become extinct. It would seem that they ran out their stock and its tendencies. But their cousins, taking a different line of progression, have left capable descendants. All the living forms are related after the manner of cousins many times removed. In the line of descent it is quite clear that the birds came from the reptiles. They are cousins of the mammals and man. These sprang from the reptiles as well. The reptiles are descended from the amphibia and they are descended from the fishes. The insects and the fishes are the descendants of the worm stock. The process has taken perhaps 50,000,000 years. It required for the forms which lived on land the permanence of the continents in their fixed places above the sea. It demanded for this great period of time a wonderfully nice adjustment of temperature. If the range of temperature had been above 200 degrees F., or much below—50 degrees F., even very occasionally, life would have been blotted out. Our atmosphere tempers the sun's rays and holds in the heat in exactly the right amounts and it has done so for many millions of years. No other body in the heavens is known to have an atmosphere right for doing this. It is clear that life as we know it would be an impossibility on any of the bodies which the astronomer studies with his glass. There is no chemical element in matter organized in life which is not found in matter that is not living. An almost infinitely small amount of matter is in living things as compared with all the rest. Life exists on the highest mountains, and in the deepest seas, but mountains and seas together are only a film over the earth, eleven or twelve miles in 4,000 on the earth's radius. It is probable that living matter is so small in amount as to cover the surface of the earth, were it evenly and continuously made to cover it, only to a depth of a few inches.

Life then has persisted as a thin film over the earth's surface continuously for many millions of years, and all living things are related as collateral branches of one family. They have lived under conditions involving a very narrow range of temperature changes, and of slight variations in the quality of the air they breathe. We, as men, look back on an exceedingly long ancestry. Each generation has the miraculous power of handing on the wealth of garnered experience of life. We hold this store of knowledge, the heritage of ages past, as trustees, on behalf of the generations to come.

Excursion 10.

Coal in the Colorado Springs Region.

IN the Colorado Springs region beds of coal of variable thickness are found almost continuously from the bluff a mile northwest of Pikeville station to Franceville, 12 miles east of the city. Over this stretch except for a few miles this side of Franceville, there is a line of coal mines and prospects which is nearly continuous. Coal is found as well along the Atchison, Topeka and Santa Fe tracks farther north.

The place for the formation of coal is in the midst of the sedimentary rocks. It may be thought of as being a sedimentary rock itself. Coal is what is left of woody tissues that have been in large measure saved from decay by having fallen into the quiet waters of a swamp. When a tree drops to the ground in a forest its substance is quickly dissipated and in time only a slight mineral ash is left; but a tree-trunk which is buried under water is out of contact with the air and it is largely protected from decay. Quiet swamps bordered by trees and partly choked by a vigorous growth of mosses, are favorable places for the gradual accumulation of carbonaceous material under water. Swamps are commonly found in low lying districts near the sea-coast. A slight change in the stand of the land with reference to sea level would bring the ocean waters over the spot occupied until then by the swamp. Layers of sand or mud might then be deposited on the sea floor above the coal to form sandstone or shale in later geologic times. The coal layer undergoes great compression in the midst of the sandstones and shales of the sedimentary rock series.

Carbon and oxygen are the principal elements in wood. It also contains a little hydrogen and a little nitrogen. The changes from woody tissue to coal may be noted through many stages. The losses are chiefly in the oxygen which is given off. Most of the carbon remains, so that relatively it comes to be more and more of the residue until in lignitic coal it is 60 per cent. as against 16 of oxygen. In anthracite coal it may be 90 per cent. of the whole, oxygen 3, hydrogen 3, and the remainder chiefly mineral ash. The whole mass of woody tissues is pressed together by the weight of the sedimentary layers above until almost every trace of leaves and stems is lost. Only occasionally the imprint of a fern may be discovered. Long afterwards the rocks may be deeply cut into by rivers until the coal layer is exposed on either side along the valleys.

If the observer will take the Denver and Rio Grande Railroad to Pikeville station, and proceed along the little east-west valley (Douglass Valley) which he first encounters on the west side of the railroad track going north until he comes to a point 100 paces beyond the brick works, he may see the coal outcropping on either hand. As formerly mined the seam stands about 15 feet above the road. It is 4 feet in thickness and nearly level. The rocks in which it lies are chiefly sandstones. Immediately above it is a layer of fine shale in which fossil ferns may be found. In many places the slide rock has fallen down the valley side in a way to cover up the outcrop of the coal. The series of the sandstones in which the coal is found, about 125 feet in thickness, crosses Monument Creek near Pikeville station and runs in the gently sloping ground around the lower slopes of Austin's Bluff to the southeast for 12 miles. The several coal mines along or near the line of outcrop serve to mark its position.

At the Williamsville mine an inclined opening is used to take out the coal. This is also the case at the Danville mine northeast of Colorado Springs where the incline goes under ground with the layer of coal at such a rate that after 100 feet it is 10½ feet below the surface. In most of the mines the coal is won by sinking a shaft some distance back from the surface outcrop until the coal is met at depths of 100 feet or less. Near Austin's Bluff there is a thick layer of loose adobe clay washed by the rains down hill from the bluff. This covers up and conceals the outcropping edge of the coal seam. The layers of sandstone and shale underlying those which contain the coal were deposited in the usual manner on the sea-floor. It is evident, therefore, that upward movements were needed to raise them out of the water as a land mass on which the coal accumulating swamps flourished. Afterwards the land sank beneath the waters, and sandstones were deposited in place above the spot. By the pressure of these rock layers the seam of vegetable tissues was much thinned. A tree trunk a foot in diameter makes an inch or less where it lies in a coal seam. It is evident that the swamp generally covered but a small area; for this reason coal seams grow thinner and at last disappear at the limits of the swamps in former time. To the northeast of Colorado Springs coal has been found 20 feet in thickness. This is unusual. Often three or four seams of coal each 2 or 3 feet thick show one above another.

An ideal coal seam should be about 6 feet thick to give room enough for work upon it. If it be 3 feet or less a great deal of waste rock must be taken out with the coal in order to get at it underground. If the seam be much thicker than 6 feet it is necessary to put in timbers to hold up the roof, and this is always expensive. Much trouble is made by a weak roof where for instance a loose shale lies overhead, and keeps falling down when once it is exposed by the removal of the coal. Coal must be free from pieces of shale or other rock to be marketable. It is not uncommon to find a layer of shale in the midst of a coal seam, representing that much mud deposited in the swamp in which the coal forming plants were accumulating.

The coal seams near Colorado Springs are not greatly inclined away from the horizontal. Layers of coal, like the sedimentary rocks in which they lie, are often steeply inclined, so that they go down into the ground at a sharp angle. Mining is then expensive, for the cost of taking out coal increases rapidly on a seam pitching so sharply down that to get the coal deep mining is necessary almost at once. In the mines near Colorado Springs coal is broken down from the face of a seam in the chambers by the use of dynamite. The ton or more which falls as the result of a shot is drawn out to the surface in cars along an incline or hoisted in a shaft.

The supply of coal in the world is limited. It is now being mined and consumed at something like 1,000,000,000 tons a year. There is not enough of it to last for much more than 150 years at this rate. It took a long time for nature to gather carbon in such amounts from the atmosphere through the medium of plant life. Leaves are provided with an apparatus for gathering carbon from the air in sunlight. The carbon in the atmosphere is contained in the gas carbon dioxide. This is broken up by the chlorophyll in the leaves, with the aid of sunlight, and the carbon made into the plant body. No animal is able to gather carbon, and the other elements which it needs, directly from the inorganic world. Plants alone can do this. Animals are absolutely dependent for their existence on plant life, and plant life exists only in virtue of the ability of the leaves to break up the carbonic acid gas in the air and store carbon in their bodies. Coals differ in the amount of carbon and other elements which they contain, and their differences result from the amount of change which the woody tissues have undergone since they were imprisoned between the layers of sedimentary rock.

When a study of the way in which coals burn is made, it becomes clear how the several kinds of coal, lignitic, bituminous, and anthracitic differ. If a small quantity of coal, powdered finely, be taken and heated in a metallic cup or crucible, (the crucibles used are made of platinum), at a temperature of 107 degrees F., a certain amount of moisture will be driven off. Until then the coal can not be said to be dry. By weighing the thoroughly dry coal and subtracting the result from the original weight the actual amount of moisture is obtained. Coals contain from 1 to 20 per cent. of moisture, and as the coal burns, this must be converted into steam and driven off before the heat of the coal becomes available. With a higher heat, (that given by a Bunsen flame is used), another part of the coal is burned up in seven minutes. This part consists of what are known as the volatile hydrocarbons. The gas made from coal is a product of this part, the volatile hydrocarbons. Weighing again, this loss is found. Afterwards it takes an hour or more over a hot flame to burn up the fixed carbon. This is the chief heat giving element in the coal. In anthracite coal the fixed carbon is five or more times as abundant as the volatile hydrocarbons. In bituminous coal it is from one to five times as abundant. In lignitic coal the fixed carbon is always less abundant than the volatile hydrocarbons, so that the ratio between the volatile hydrocarbons and the fixed carbon obtained by dividing the amount of volatile hydrocarbons by the fixed carbon is less than one for lignite. After the moisture and volatile hydrocarbons have been driven off, and the fixed carbon burned, nothing but mineral ash is left. This ash is really the sand or mud which was dropped in the swamp waters in the midst of the vegetable layers as an impurity. In good coals it is 8 per cent. or less. When it is easily fusible it leads to clinkers in the fire as the coal burns. The Colorado Springs coal, while it is high in moisture and in ash, is an unusually good clean lignite. Lignite is not as valuable as bituminous or anthracite coal because its heat-giving power is less. The amount of moisture is usually high in it, and the conversion of the moisture into steam by the coal as it burns means just so much loss of heat. Many lignites show high percentages of the impurities which are left as ashes.

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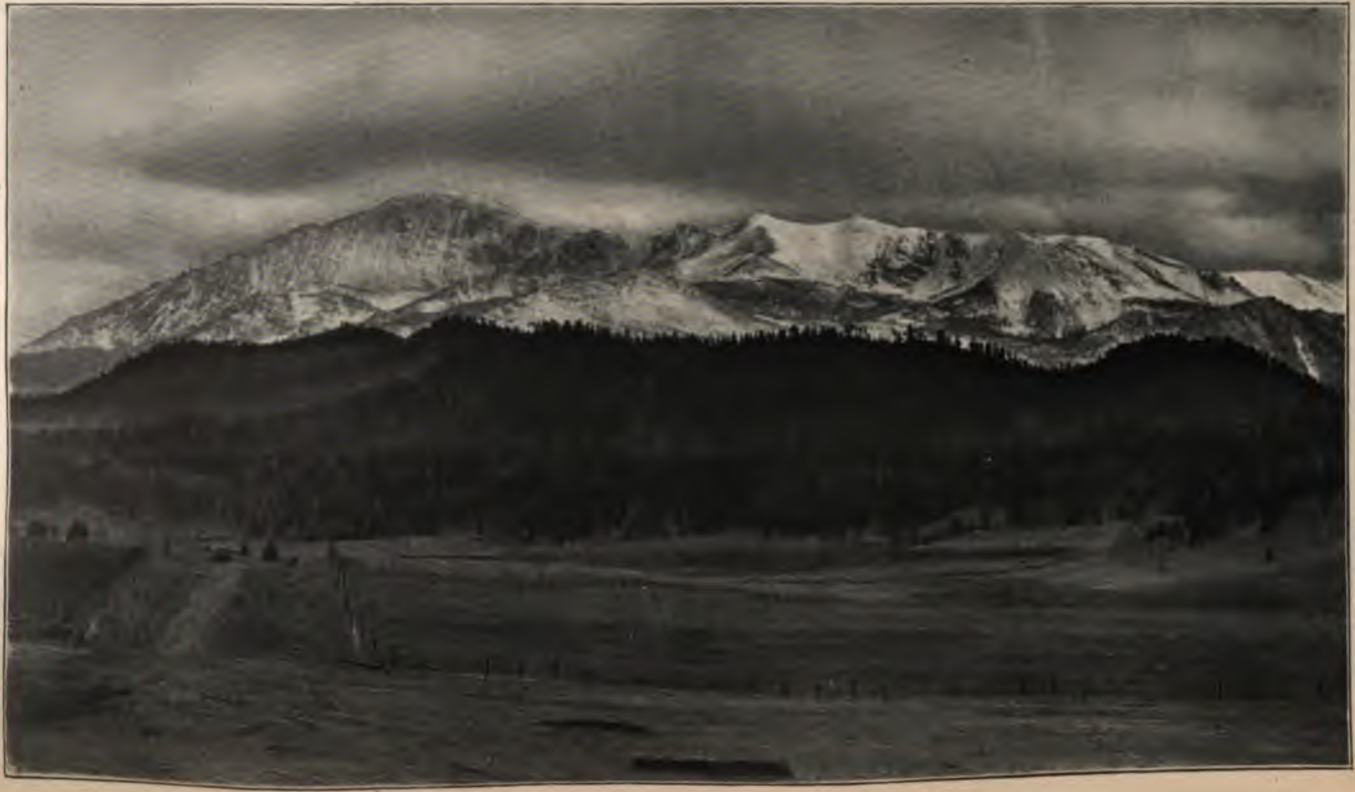

PLATE 37.—PIKE'S PEAK FROM MANITOU PARK.

Excursion 11.

The Cripple Creek Ore Deposits.

IT is an almost invariable rule that the occurrence of gold ores in veins is bound up with some manifestation of volcanic activity. Cripple Creek is on the site of an extinct volcano. The converse, that volcanic outbreaks bring gold to the surface, is, in the vast majority of cases, not true. There is only a possibility in a given case that valuable metals will be found associated with volcanic outbreaks. But regions where igneous rocks are abundant are the favorable places for prospecting.

The amount of gold present in a ton of the rock taken out at a profitable mine is an extremely small fraction of one per cent. If the reader will think of a ten dollar gold piece so finely broken up that the particles are for the most part invisible, and then suppose them to be thoroughly mixed with a ton of powdered rock, he will have a fair picture of the tenor of a deposit of a fairly good gold ore. Gold is never equally distributed throughout the rock that makes up a region. It is apt to have come with minerals that are of no value, such as quartz, to fill up crevices in the country rock. The transporting agent was usually heated water. When a great crack in the rock has been filled it is the rule to find as one follows it along the ground that in some places it carries rich values, while in others it is lean. The true value can not be determined on the ground. The assayer must actually extract the invisible gold from a small portion of the rock and so calculate the value of a ton.

The manner in which the Cripple Creek rocks were built up and suffused with the gold brought to them in heated waters was as follows. The original rock over the country was the granite that one finds everywhere in the Front Range in Colorado, part of the original island in the Colorado seas. (Excursion 1). In late geologic times a normal volcano broke up through the granite with explosive violence. A volcano is the coming of molten rock to the surface from the interior portions of the earth. The earth itself is not molten, nor is any considerable portion of it in the molten state. It behaves like a rigid body in its relations to the other members of the solar system. The earth's mass is held together by its own self-gravity. Gravity all the while makes for a more compressed earth. The shrinkage of the planet under gravitative control is slight, but one effect of the compression is the generation of heat, and its gradual accumulation in the deeper zones of the earth down from the surface. Since in volcanoes fused rocks do actually come to the surface it is believed that the deep seated rock is from time to time in one place or another rendered molten, where heat has accumulated sufficiently. In the fused state it is lighter than the surrounding rock. The readjustment of gravitative stresses means that the lava will thread its way to the surface. We find that the surface manifestations of volcanoes are chiefly controlled by the efforts to escape of enormously heated gases which have come up with the lavas. When they are hindered in their passage up through the molten rock in the vertical pipe line of a volcano they may accumulate until they blow everything out of their way with explosive violence. They act on the molten lava in the pipe as though water were shot out of a gun. In the upper air the finely divided lava becomes solid and falls around the volcanic vent as lava dust. We find beds of such volcanic dust many feet thick in the Cripple Creek district. Lavas, later, flowed out quietly from the volcano on all sides.

It was only after all these operations of the volcano had ceased that the gold was brought up. The ashes had been cemented together as firm rock beds. The lavas became cold and hard. Much later all these rocks in the district, together with the basal granite, were subjected to such strains in the uppermost zone of the earth that they were thoroughly cracked and broken up. The observer on his way to Cripple Creek may see from the train that the rocks are cut by thousands of vertical and inclined cracks. Long after the volcano was cold and dead at the surface high temperatures were maintained below by the lavas which had not even then lost their heat. Heated waters rising from the depths of a few miles brought up the gold dissolved with them, and worked through the cracks in the rock of the Cripple Creek district on the site of the volcano, and near it, depositing the gold as they became cold and evaporated. In other words they deposited a gold bearing mineral together with valueless minerals in the cracks of the rocks. As being of no value these last are called gangue minerals. Fluorite is one of the commonest. It is usually purple and gives the rock which it has impregnated that color. The valuable part of the ores is the mineral called sylvanite. It has a silvery color and is made up when pure of three elements, gold 26 per cent., and silver 12 per cent., compounded with another native element, tellurium. Tellurium is an element like sulphur.

The traveler who visits Cripple Creek or Victor sees little which suggests to him the characteristics of the district as outlined above. The volcanic mountain, together with everything else over the upland country, has been worn down by the forces of the weather, frost, and cutting streams to one general level. One sees only the roots of the volcano. He may pick up pieces of the lava, but its accurate determination as phonolite required in the first place extended chemical work and microscopic examination on the part of the U. S. Geological Survey. No one finding it in the field could be absolutely sure which of the lavas it was. If the traveler goes down into a mine, in all probability he will not see any gold. The mine is a shaft sunk in the ground from which at successive levels tunnels run off horizontally through the solid rock. Their object is to encounter the fissured portions of the rock which happened to be in the way of the gold bearing ascending hot waters. A miner may show him a piece of rock from the wall of a fissure bearing upon it crystalline masses of the silvery mineral which contains the gold, and the associated purple fluorite; but for the most part the rock, broken up as it is with countless cracks, looks much alike, and seems to have no metallic values. Only the assayer can determine its contents. When he has once assayed it the miners in their orderly procedure as they take out the rock at the ends of the tunnels look for the precise rock which has been assayed and found rich. They become expert in following it, but would go much astray if the determinations of the assayer from day to day did not direct their attention to the most valuable rock. The granite of some mines was impregnated by the solutions. Again the lavas or the beds of consolidated lava dust contain the values. Why it is that on the site of the Cripple Creek volcano gold came up in solution with the heated waters, whereas at many other similar volcanoes dealing in the same rocks the waters came up barren we have at present no means of knowing. Such a criterion would be of transcendental value to the prospector.

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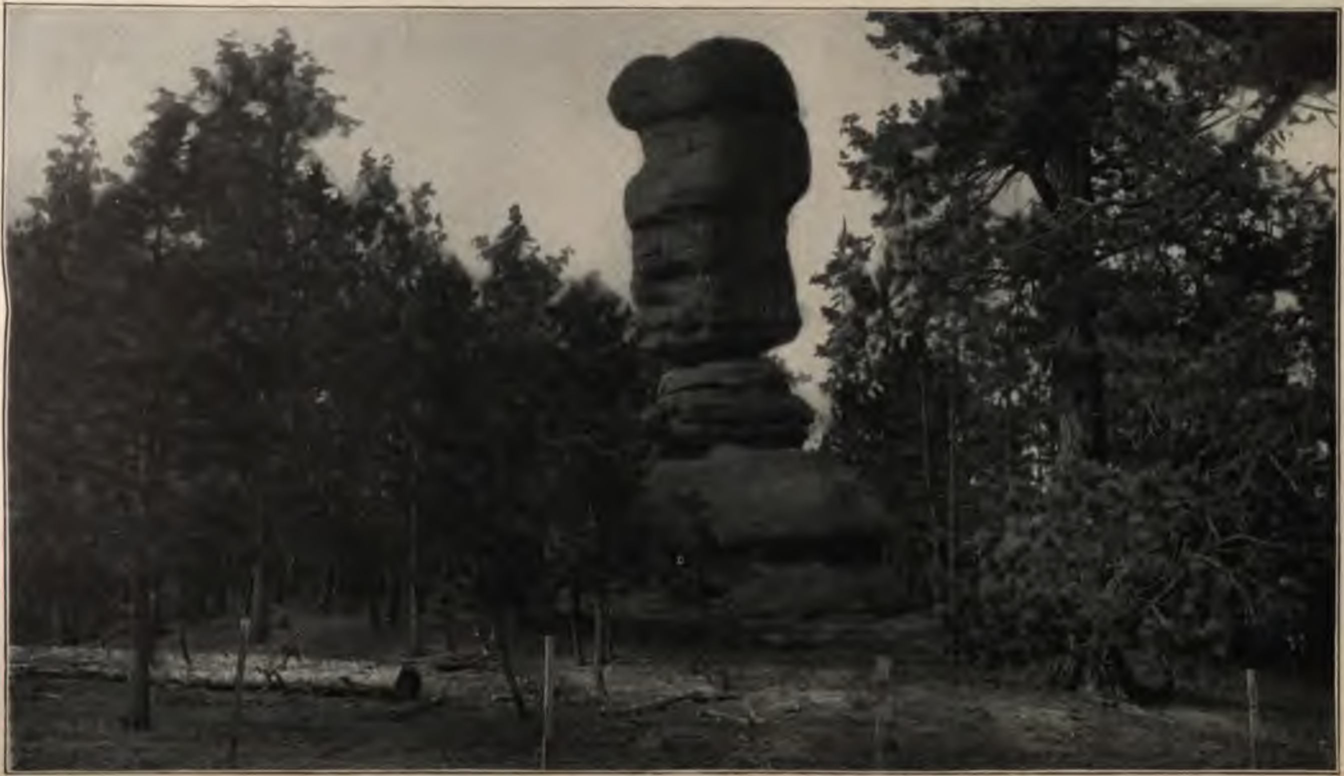

PLATE 38.—EROSION COLUMN OF CONGLOMERATE IN MANITOU PARK.

Excursion 12.

Manitou Park.

THE traveler may notice from Colorado Springs that the tops of the mountains to the north of the Ute Pass lie nearly in one plane. Their highest points are all that is left of an upland into which the rivers have cut deeply. From Pike's Peak the observer looks down on this great upland of granite out of which the mountains have been carved. In places the upland surface has been but little dissected, and broad gently rolling stretches, heavily timbered except on the meadow lands bordering the streams, make a striking contrast in their loveliness to the rugged scenery near the city of Colorado Springs itself. Of these park-like areas Manitou Park is the most interesting geologically and the most beautiful. The way into the park is by the Midland Railroad to Woodland Station and then by stage northward for eight miles. The excursion calls for a day and a half. Accommodations are provided at the hotels in the heart of the tract now owned by the Colorado College school of forestry.

Much more impressive than its familiar eastern face is the northern flank of Pike's Peak as viewed from Manitou Park. Plate 37. On the northern slopes of the mountain two very interesting depressions mark the sites of small glaciers which formerly existed in them. They are in all ways comparable to the glacial amphitheatre on the Colorado Springs side of the peak, figured in Plate 30, and the account of its manner of formation is applicable to them.

The amount of differential uplift as between the mountain upland to the north of the Ute Pass, (which the Midland Railroad follows), and the mass of Pike's Peak, is seen in its full significance from Manitou Park. In the readjustments of the rocks near the earth's surface necessitated by a slowly changing interior (see page 17), which is becoming all the while more and more condensed, it frequently happens that nearly vertical fissures are made across the rock masses. On one side or the other, to ease the strains below, a segment of the earth's surface is forced up. When this happens suddenly, although the movement be slight in actual amount, not more than a few feet, the rocks grind past each other and the vibration which is set up in them is an earthquake shock. The movement of this kind which may give rise to an earthquake shock is known as faulting. A fault is a break across layers of sedimentary rock or in the midst of igneous rocks along one side of which there is movement up or down. See diagram Fig. 2, Plate 16. The uplifts once begun along a great fault-line are likely to continue at intervals. The faulting along the Ute Pass which has lifted the Pike's Peak block fully a mile above its fellow to the north, on the Manitou Park side, was not accomplished at once but by a long series of movements. By going for a quarter of a mile up along the little stream which comes down to the Manitou Park hotel from the east and climbing the ridge of white sandstone at the sawmill one may see where the sandstone and granite meet on either side of the fault line. The granite to the east has been thrust up much above its normal position. It once lay below the red and white sandstones. By the drag of the fault the white sandstone has been pulled up on end where it abuts against the granite. At a little distance westward from the fault line the faulting effects are not seen; for over nearly all of the park the red conglomerates and sandstones are but slightly inclined away from their original nearly horizontal position.

The rock over Manitou Park is the same red conglomerate, (the Fountain formation), that comes to the surface west of the Garden of the Gods. Between the two places for a distance of several miles it has been entirely cut away by erosion. The Manitou Park conglomerate is therefore an outlying mass of sedimentary rock quite by itself in the midst of the granite. Over the interior portions of the park the conglomerate has been covered by river laid sand and clay. It outcrops along the borders of the park, and wherever erosion has not attacked its mass as effectively as it has generally. In such cases columnar masses too high to be covered by the sand and gravel have been left. One of these similar to the Balanced Rock near the Garden of the Gods, Plate 11, is found along the road one-eighth of a mile west of the school-house in Manitou Park. It is shown in Plate 38.

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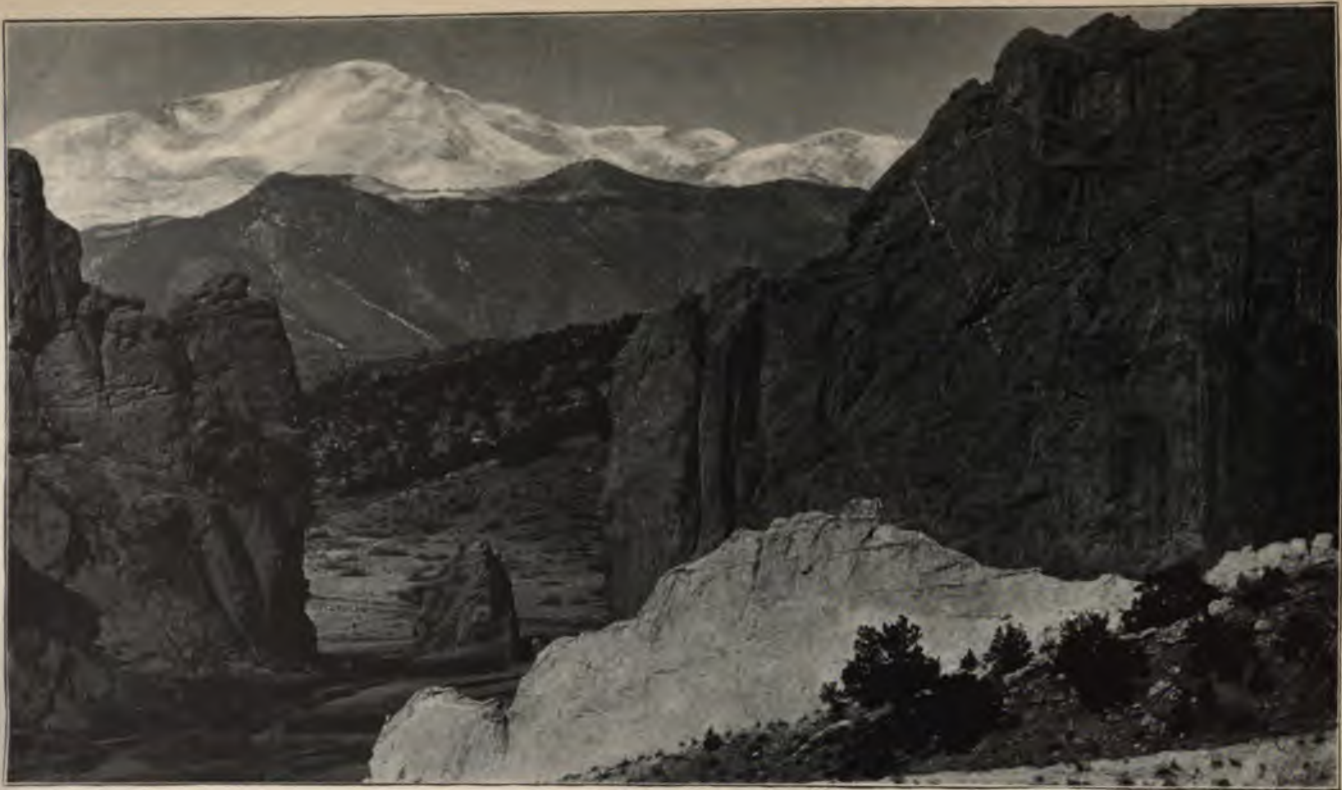

PLATE 39.—GATEWAY, GARDEN OF THE GODS.

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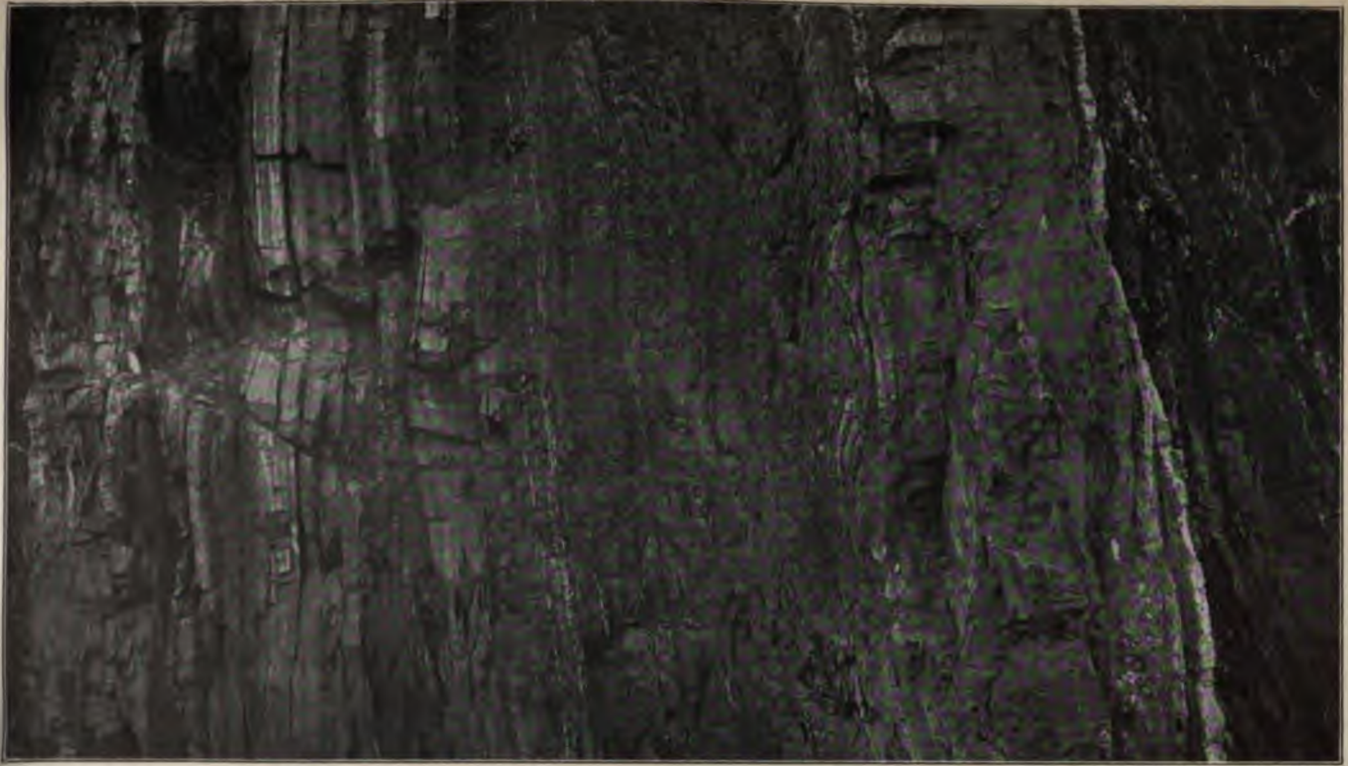

PLATE 40.—SEDIMENTARY BEDS OF SHALE, SANDSTONE AND LIMESTONE STANDING VERTICALLY AT THE ENTRANCE TO RED ROCK CANYON, BETWEEN COLORADO CITY AND MANITOU.

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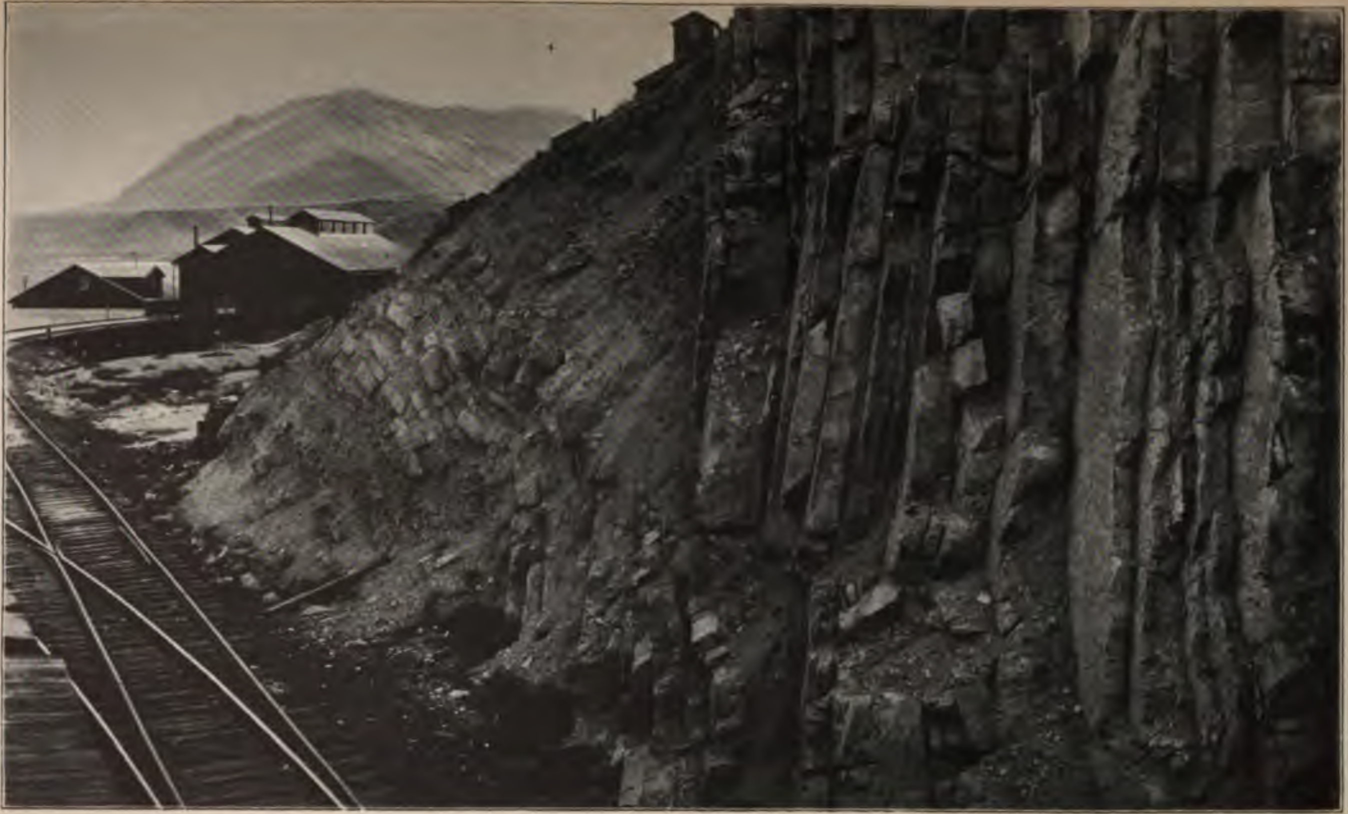

PLATE 41.—NIOBRARA LIMESTONE. RIDGE WEST OF UNITED STATES REFINING AND REDUCTION COMPANY'S MILL.

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Summary of the Geology of the Colorado Springs Region.

I.	II.	III.	IV.
Pleistocene	(17) Mesa gravels		Plate 35, ridge extreme right of background.
Pliocene	Not represented.		
Miocene	Not represented.		
Oligocene	Not represented.		
Eocene	(16) Conglomerate and sandstone	Monument Creek.	Plates 21, 22, 25.
	(15) Sandstone	Denver.	
	(14) Sandstone	Laramie.	
	(13) Sandstone	Fox Hills.	
	(12) Shale	Pierre	Plate 18, plains in the background.
Cretaceous	(11) Shale	Niobrara	Plate 35, low ground to right of ridge.
	(10) Limestone	Niobrara	Plate 41.
	(9) Shale and sandstone.	Carlisle	Plate 35, crest of ridge.
	(8)*Limestone	Greenhorn.	
	(7) Sandstone	Dakota	Plate 15, extreme right.
Jurassic	(6) Shale and sandstone.	Morrison	Plate 39, white sandstone in foreground.
Triassic (?)	(5) Sandstone and shale.	Upper Wyoming.	Plate 40.
Carboniferous	(4) Conglomerate Sandstone and shale.	Fountain	Plates 11, 12, 39.
Devonian	Not represented.		
Silurian	Not represented.		
Ordovician	(3) Limestone	Manitou limestone	Plates 9 and 10.
Cambrian	(2) Limestone and sandstone		Plates 4, 6, 8.
Algonkian	Not represented.		
Archean	(1) Granite		Plates 1 and 19.

A study of the above table of formations in the Colorado Springs region is the best introduction to the account of the geology in general terms. In column I. a complete list of the time names is given, the oldest, the Archean, at the bottom, and the youngest, the Pleistocene, at the top. The

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*Note.—Between the Dakota sandstone and the Greenhorn limestone a band of shale, the Graneros shale, is met. It is inconspicuous in the Colorado Springs region.

oldest formation is the granite of the mountains, which is of Archean age; the youngest the gravels capping the mesas. These are Pleistocene and recent. In column II. the several kinds of rock near Colorado Springs corresponding to the time names are set down. Geologists have given to many of the rocks in the Colorado Springs region local names. These names appear in column III. In IV. the references appear, showing which of the plates in the text illustrate the several formations. By working from the plates one may visit the localities where the sedimentary rocks appear in good development.

For some of the time periods such as the Algonkian, Silurian, and Devonian, there are no representatives near Colorado Springs. In any locality of like extent we expect that but a few of all the periods will be represented in the rocks. The section near Colorado Springs is unusually complete. An acquaintance with it gives one the key to the sedimentary rocks along the front of the Rocky Mountains from New Mexico to Montana, for while they are not exactly alike, yet there is great similarity between the rocks from point to point all along, and their succession is the same. Some of the bands of sedimentary rock are continuous along the Front Range for over 200 miles. The rocks west of Denver near Golden and Morrison repeat in large part the section west of Colorado Springs. At Canon City the same rocks show again. Beyond the Continental Divide in Western Colorado the same rocks in general occur and they bear the same relations to the basal granites as they do along the Front Range. Such a wonderful continuity in the sedimentary rocks points to uniformity over wide areas of the conditions which produced them. The account of the geologic history of the Colorado Springs region is in fact bound up with the geologic history of the Western United States.

The first chapter in this history is recorded in the granite of the mountains. We know that this is the oldest rock in the district because it is the platform on which the

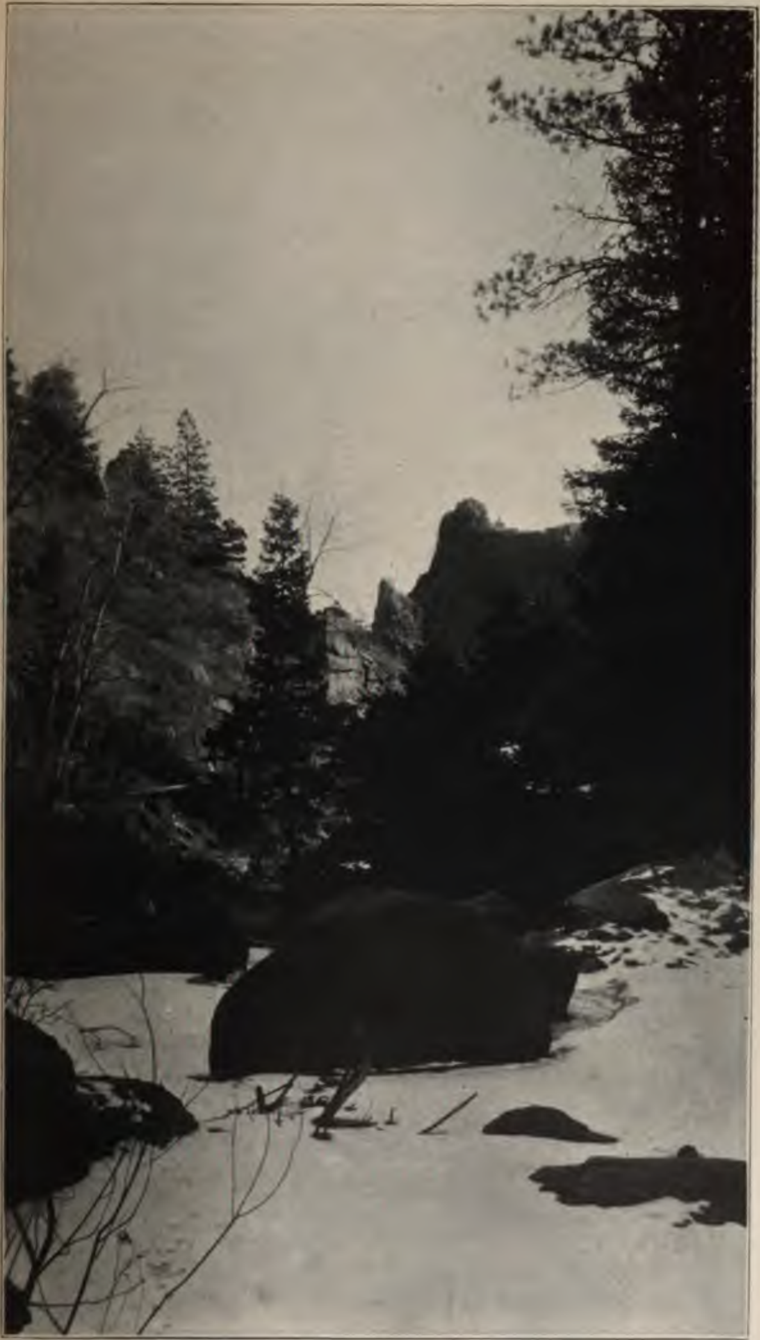

PLATE 42.—BOWLDERS IN THE BED OF NORTH CHEYENNE CREEK, HALF A MILE UPSTREAM FROM THE ENTRANCE TO THE CANYON.

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later rocks rest; and we find, as well, that the materials of which they are made came from it. The next oldest rocks, the Cambrian sandstones, come in just above the granite; their age is proven by the fossils which they contain. It is a rule that as we go out from the mountains towards the plains younger rocks are met. Thus at the base of the series in Manitou Canyon and the Ute Pass Cambrian sandstones occur overlain by Ordovician limestones. Carboniferous rocks extend beyond these as far as the Garden of the Gods. Colorado Springs is built over the Pierre shale of Cretaceous age. This is the shale exposed along the paths in Monument Valley Park and split up irregularly into thin, small rectangular pieces. Austin's Bluff is in still higher younger rock laid down in Eocene times. These Eocene conglomerates make up the whole of Monument Park. They lie close to the granite all the way north to the divide at Palmer Lake where they rest directly upon the granite. The whole story is, then, in brief, the adding of sedimentary rocks to an original island mass of granite by deposition in the sea along its shores, and the subsequent making of them into land by continental uplifts and the concurrent retiring of the sea. Western North America was covered by the ocean until the end of the Cretaceous period. In Silurian and Devonian times there were uplifts which maintained the Colorado Springs area above water as a land mass. Over the spot the work of down cutting by the forces of erosion went on during those periods. It was only when the worn down land had been carried once more below sea level that the formation of sedimentary rocks under water began again. The early Carboniferous sandstones contain land plants among their fossils; in later Carboniferous times marine conditions prevailed, and continued until the end of the Cretaceous. Then, in the Laramie period, the country was above the ocean level. It supported the low-lying coast swamps in which woody tissues accumulated to be later consolidated and made into coal. The Denver formation is a soft sandstone the grains of which are volcanic ashes. These are believed to have been deposited in a fresh water lake. Such a lake very possibly existed in Eocene times. The Monument Creek formation may have been such a deposit: it contains palm leaves, the leaves of deciduous trees like the willow, and the bones of huge reptiles. On the other hand these Eocene deposits of the Monument Creek formation may be such river-laid deposits as the mesa gravels. They are, however, much more extensive. In Oligocene times a lake existed near Florissant some 20 miles northwest of Pike's Peak. It appears that the Monument Creek formation belongs partly to the Oligocene period, partly to the Miocene. In Miocene times the Cripple Creek volcano broke out through the granite. The latest formation of all is the Mesa gravels. Additions are slowly being made to them at the present day. They represent approximately the time during which man has lived on the earth. The mammoth was a contemporary of early man, and the teeth of this creature have been found near the base of the gravels.

At the north end of Monument Valley Park the walls on either side of the waterfall are faced, from the base upward, with the rocks which correspond in their order to the rocks in the geological section for the Colorado Springs region. These are the rocks, from 1 to 10 inclusive, in column II. of the table on Page 66. Monument Valley Park lies over the Pierre shale. (No. 12). It is the series which one meets in crossing from the mountains to Monument Valley Park. At the base is granite (No. 1 in the table); just above this is the Cambrian sandstone, and so on upward. The section Fig. 3, Plate 42, is numbered in the same manner.

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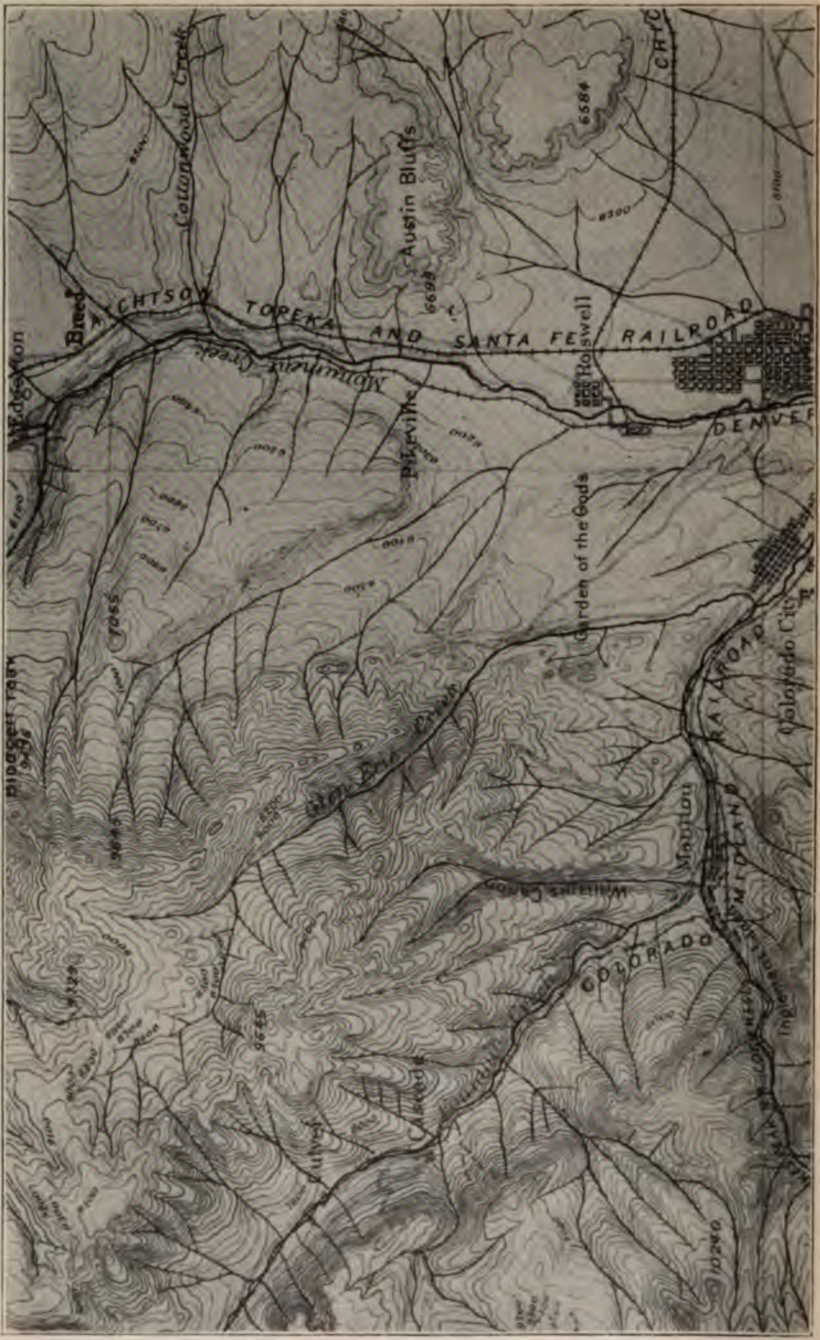
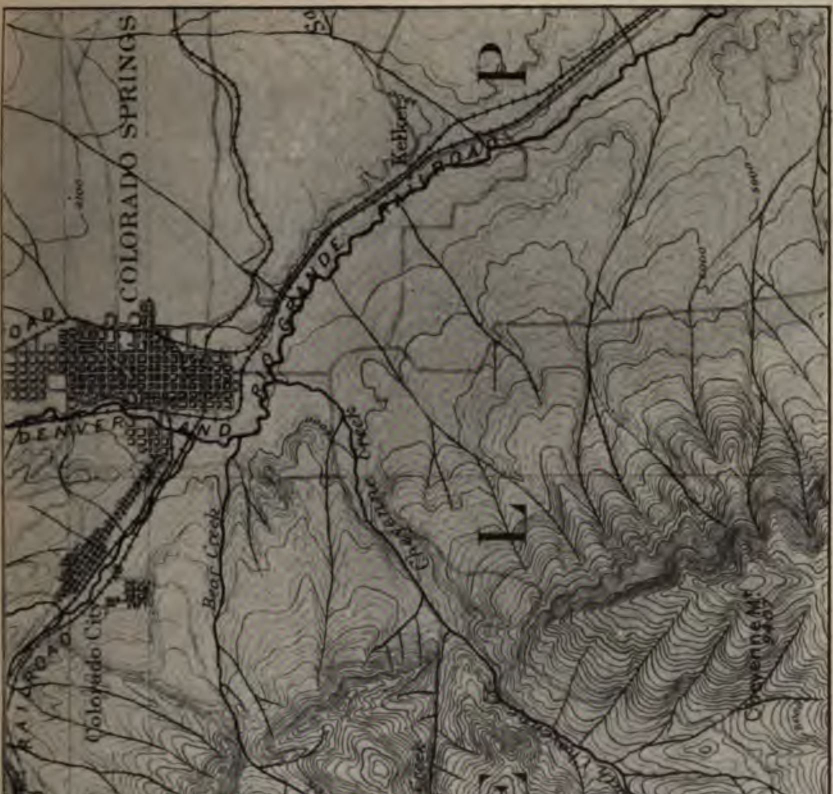
MAP OF THE COLORADO SPRINGS REGION. SCALE, TWO MILES TO THE INCH.


Edgerton
Breed
ATCHISON TOPEKA AND SANTA FE RAILROAD
Cottonwood Creek
Austin Bluffs
6584
6698
Roswell
Monument Creek
Pikeview
DENVER
Garden of the Gods
Colorado City
RAILROAD
MIDLAND
COLORADO
Manitou
Williams Canon
Blodgett Peak
9438
9645
9329
7055
9625
Cascade
10240


COLORADO SPRINGS
Colorado City
DENVER AND RIO GRANDE RAILROAD
COLORADO MIDLAND RAILROAD
Kelker
Bear Creek
Cheyenne Creek
Cameron Cone
Cheyenne Mt.
Mt. Rosa
Ruxton Creek
MANITOU AND PIKE'S PEAK
10290
E L P